PATTERNS OF LIFE

BY THE SAME AUTHOR

Social Biology (*Heinemann*)

PATTERNS OF LIFE

by

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Illustrated with drawings and photographs by the Author

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FIRST PUBLISHED 1949

PUBLISHED BY
WILLIAM HEINEMANN LTD
99 GREAT RUSSELL STREET, LONDON, W.C.1
PRINTED IN GREAT BRITAIN BY THE PUBLISHERS AT
THE WINDMILL PRESS, KINGSWOOD, SURREY

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Acknowledgements

I HAVE to thank many friends for their assistance in the preparation of this book.

Messrs. L. C. Comber, M.A., James McCloy, B.Sc., Richard Palmer, B.Sc., and Eric Lucas, M.A., made constructive criticisms of the original outline scheme, and together with W. H. Palmer, M.A., and A. W. Pritchard, M.A., subsequently read and criticised the manuscript. My former teacher, L. P. Ibbotson, M.A., also read the manuscript and pointed out several errors.

I have to thank C. B. Shore for Figs. 1 and 74, also for providing the sketches from which Mr. E. B. Woodall prepared Figs. 119, 120, 121, 122A; and 122B. Mr. Verdun Hughes drew Fig. 116, and gave advice on Chapter XXI.

I must thank my former pupils D. B. Hope and R. M. Brown, of King Henry VIII School, Coventry, for Figs. 140 and 58 respectively. D. B. Hope also gave assistance over a long period in obtaining specimens.

Mr. E. Willes was good enough to prepare the key to the cultivated legumes, and Mr. L. Leather, B.A., worked out the pronunciations.

Figs. 145 and 59 are from Wheeler's *Essentials of Biology* (Heinemann). I am indebted to Messrs. Methuen for permission to reproduce Plate VI from Cott's *Adaptive Coloration in Animals*; to Messrs. Witherby for permission to reproduce Figs. 115 and 117; to Messrs. Duckworth for permission to use Fig. 112. The information on which the key to the British Woodlice is based came mainly from Sillem and Webb's *British Woodlice*. Plate V is taken from my *Social Biology* (Heinemann) and was originally prepared from photographs supplied by Prof. H. W. Miles of Wye College. The arduous work of reading the proofs has been undertaken by H. L. Hoyce, M.Sc., and W. E. Summerhays, B.Sc., to both of whom especial thanks are due.

Finally I should be ungrateful not to record the willing collaboration of two other people: Alan Hill, of my publisher's Educational Department, in whose mind the book was first conceived, and who has subsequently done everything possible to facilitate smooth production; and to my wife who has uncomplainingly tolerated much upsetting of household routine and domestic arrangements.

Preface

Patterns of Life has been written in the conviction that there is a need for a book describing the natural history, and such details of the external structure as can be seen with the naked eye or the aid of a good hand lens, of common plants and animals.

Too many students of biology are familiar with the microscopic appearance of tissues and organs of plants and animals, while they are unfamiliar with the appearance of the whole organisms; have no idea where to search for living specimens; and are quite ignorant of their natural history.

Since so much of the biology of living organisms has significance only in relation to the lives led by those organisms in their natural surroundings, there can be little doubt that a study of biology should begin with real natural history. The knowledge so acquired will illumine and vitalise the formal courses of morphology, physiology, ecology, and even genetics, that may follow later.

Unfortunately, real natural history cannot be learned in the schoolroom; nor are occasional expeditions undertaken by school classes altogether successful, because many of the more interesting phenomena of natural history do not occur to suit school timetables. Such exciting phenomena as an otter fishing, small birds mobbing a cuckoo, a mother rabbit vanquishing a stoat, the emergence of a dragonfly from its nymph, or the overland journey of an eel making its way to a river, are not seen every day. They are to be regarded as bonuses, special dividends paid to those who spend much time, in a receptive frame of mind, out of doors. Consequently, the successful teacher is probably the one who can inspire at least some of his pupils to study live plants and animals in their spare time. It is to such pupils, with whom natural history is going to become a hobby, that this book is primarily addressed. Their ages will range from eleven upwards, and they will be drawn both from the modern schools and the grammar schools.

I have myself derived very great enjoyment, and much insight into the principles of biology, from collecting various groups of organisms. I have assumed throughout this book that the student will collect one or more groups of plants or animals, or at the very least will search for and find the various specimens described. The collections themselves, when assembled, will be of little value, but it is the activity of making them that is so important.

In the Report of the Wild Life Conservation Committee on *The Conservation of Nature in England and Wales*, the following passage appears as a footnote to p. 7: ". . . the collecting of natural history specimens as a means of stimulating interest and for the purpose of acquiring knowledge, of course forms an essential part of field studies."

Further on, par. 115 lays down:

"But the fact that a very few people grossly abuse this activity (viz., collecting) must not be allowed to blind us to its importance. We wish to make it abundantly clear that we regard the collection and photography of natural history objects as a valuable method of stimulating study and bringing about that widening of public interest in nature which is essential to the lasting success of our proposals. Indeed, the scientific study of nature depends upon the collection of a sufficient array of specimens for the purposes of close examination and record. Moreover, collecting can by education be directed into useful channels. In its broadest sense it includes such widespread activities as children's birds-nesting and the picking of wild flowers."

Some surprise may be evoked by the absence from this book of chapters on birds, mammals, and reptiles. These omissions are deliberate. In my opinion birds do not, as a rule, form a good group for study by young naturalists. For those, and they are many, who develop a keen interest in birds, there are plenty of excellent bird books to be obtained. Reptiles, in most parts of the British Isles, are seldom seen, and even more seldom caught; hence, in a book whose emphasis is upon catching and collecting specimens, they have no place. Finally, I thought that it would be an ill use of the space available to discuss the mammalian pattern, because man himself, and his principal domestic animals, belong to the mammalian group.

I make no apology for the fact that no less than eight chapters are devoted to insects. Specimens of most of the insects described are easy to obtain in numbers. In most instances they can easily be reared and their life histories followed. From the great diversity of insect life in the British Isles most facets of biology can be illustrated. Indeed, the study of no other group can offer so rich a reward to the biologist.

A number of keys have been provided in the hope that their use will lead to some enjoyment, and also to some appreciation of the type of structural characters by which one species differs from another. Keys are never easy to use, and the ones given in this book suffer from the disadvantage that only relatively easily seen features have been used in their construction, and also that the use of technical terms has been avoided as far as possible. However, when several representative species are available for comparison, and when some experience in the use of a particular key has been gained, no undue difficulty should be encountered.

For many students of natural history, the plethora of scientific names frequently proves an awkward stumbling block. I think the reason lies not in any inherent difficulty in the words themselves, but rather in a student's inability to pronounce, in the absence of instruction, words that are Latin or Greek in form. In an attempt to overcome this difficulty, I have supplied a pronunciation after most of the scientific terms. For many words (e.g., species, crustaceans) biologists themselves are not agreed upon a pronunciation. Consequently, in deciding on pronunciations, I have accepted the opinion of a classics scholar. The decision not to give the pronunciations in phonetic spelling was taken after due consideration.

With very few exceptions the drawings and photographs have been made by myself from actual specimens. In two instances only have I been compelled to make drawings from photographs.

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PART I

CHAPTER ONE

How to Collect

THIS book on nature study is written to help you to know something of the plants and animals that are to be found in Great Britain. It should enable you to recognise at least the main groups to which belong the particular specimens you may find, and should help you to understand their structure, their mode of life, and the problems they have to solve in their struggle to exist. However, nature cannot be studied merely by reading books. Some facts may be learned in that way, but unless one goes out to search for and observe plants and animals in their natural surroundings, these facts can be extremely dull and meaningless things. Indeed, it is absolutely true to say that natural history can be learned only by observing living things in their natural homes, by collecting them, drawing them, and, as far as possible, rearing them.

There are so many different kinds of living things that it is difficult to know how to begin a study of natural history. Probably the best of all ways to start is to make collections of some of the more easily recognised groups. In studying and searching for them, unfamiliar forms will be met with, and in this way as one's knowledge increases, one's interests broaden.

Collecting is condemned by some people as a useless hobby; but such persons overlook the fact that the making of a collection teaches one an invaluable amount of the kind of Natural History that cannot be learned from books. It does not matter that later on the collection may be neglected and forgotten, and specimens become mouldy and eaten by mites. In making it, you will have learned the names and something of the structure and habits of many plants and animals, and some of these you will recognise as old friends for the rest of your life. You will also have come to recognise that particular plants and animals live in some places and not in others, appear at certain definite times of the year, have certain devices to keep them hidden from enemies: in short, that every plant and every animal has its own personal way of life.

At the same time it must be said that certain of our English plants and animals are now so rare that there is a danger that they will become extinct. Plants such as the Snake's Head, the Spider Orchid, and Pheasant's Eye, and butterflies such as the Purple Emperor, Large Tortoiseshell and White Letter Hair-streak, are all quite rare. It would be most distressing if we, as collectors, helped to bring about the extinction of these forms in the British Isles. It is essential not to become the type of collector who cannot tolerate an empty space in his cabinet. I suggest that you make collections of the common forms of plant and animal life that occur in distinct kinds of places. For instance you might choose to collect from one or more of the following:—a normal English oak wood, an evergreen wood, a sand or gravel pit, a heath or common, open meadowland, hedgerows, waste spaces in towns, or any other place that suggests itself. If you live in the country, you can make a most interesting collection from cornfields. After a year or two you will be interested to find the way in which your various collections resemble, and differ from, one another. On holidays you may have the opportunity to make collections from places similar to those you are already studying but in different parts of the country.

One of the greatest difficulties the young naturalist has to face is that of naming his specimens. You may find a toadstool with many tiny holes in its cap and break it open to discover a number of small insects inside. What kind of insects are they, and what is their name? Are they all of one kind? What is the name of the toadstool? These are questions which even experts might not always find easy to answer, so you must not expect too much. For most purposes it will suffice if, at first, you can recognise the group to which a given specimen belongs—a dragonfly, beetle, moth, fern, moss, or whatever it may be. In certain cases I have supplied "keys" which, with careful use, may enable you, *with experience*, to find the actual names. There are only a few keys in this book; but at the end I have added a list of books that will give you further assistance in finding the names of the members of those groups in which you become especially interested.

Equipment

In order to study Natural History properly there are certain items of equipment that you must have. Most of them can be made at home.

A magnifying glass or, as it is better called, a hand lens, is absolutely indispensable. The hand lens should be fairly powerful; if possible, it should magnify at least eight or ten times. Many lenses have their magnifying power marked on them by means of a cross followed by a number (e.g., × 8 on a lens means that particular lens has a magnifying power of 8). Those lenses which have the shortest focal length are the most powerful. To find the focal length, stand inside a room as far as possible from a window and hold the lens so that light from the window passes through the lens on to a wall, or piece of white paper, or even the back of your other hand. By moving the lens you will be able to make a small picture of the window appear. This image will be upside down. When the picture is quite sharp (in focus) the distance from the lens to the picture is roughly the focal length of the lens. A suitable lens will have a focal length of $\frac{3}{4}$ to $1\frac{1}{2}$ inches. It is possible to buy three lenses of different focal lengths in a single holder (Fig. 1). These may be used either singly or together, and so will give various magnifications.

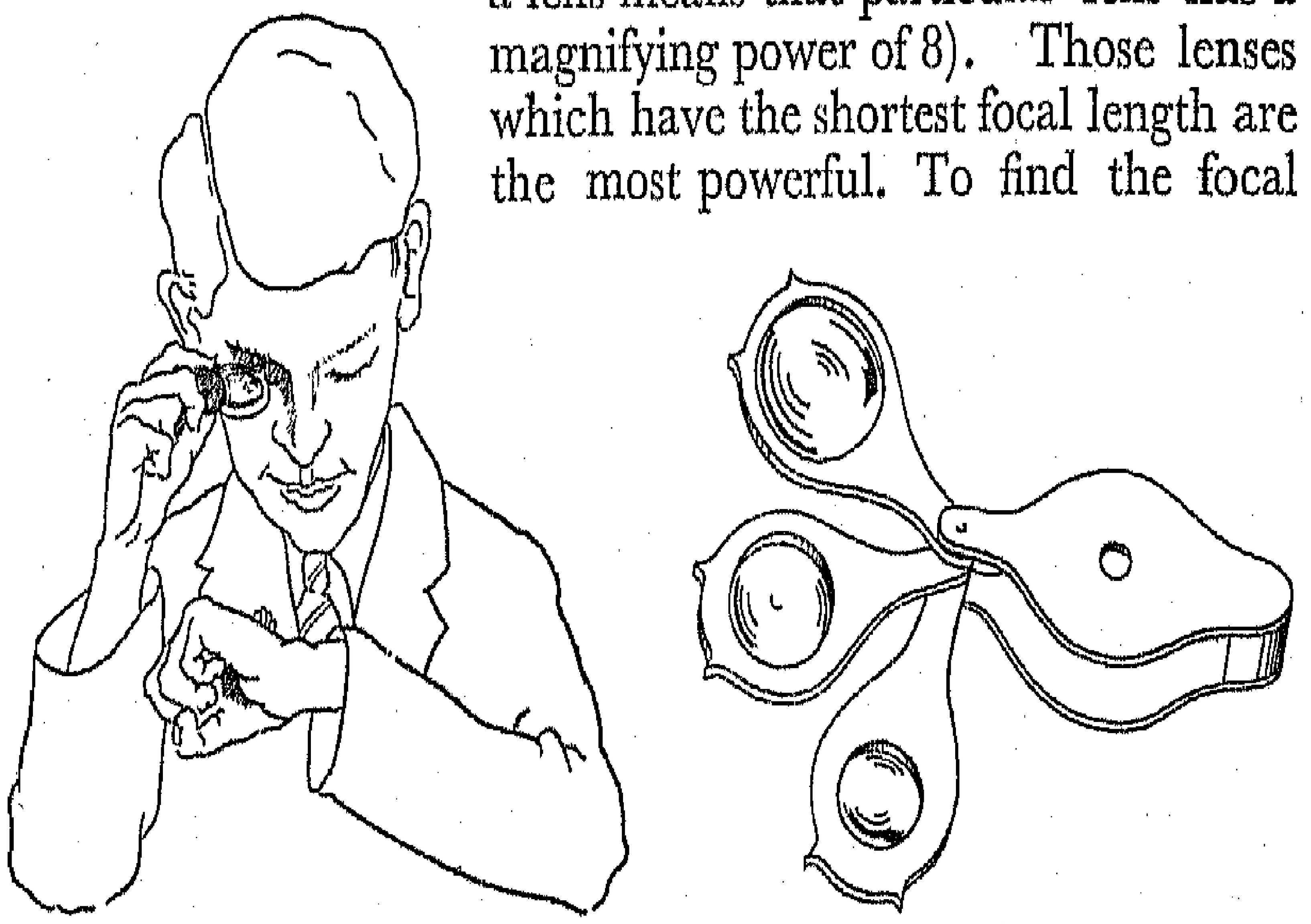


FIG. 1.—*Left:* the correct way to use a hand lens. *Right:* a useful type of hand lens, having glasses of three different powers.

Hand lenses are frequently used incorrectly. The proper way is to place the lens *close* to your eye and then to bring the object you wish to examine towards the lens until it is distinctly visible. With a lens of the power I have recommended, the object will then be only about an inch away from the glass. At first you may find that the object is not seen clearly. This is generally because you have not enough light falling on it. Remember that for success with a hand lens, plenty of light is essential. You will have to learn to hold up your head when examining objects, and not to crouch over them with your head cutting off most of the light. If you are indoors, *try to get near a window*. For examining small objects that cannot be easily held in the fingers, I find it best to place them on the back of my left hand, on the little groove just behind the knuckles of the first and second fingers. I then bring this hand, with the object upon it, towards the lens which is held in front of my eye with the right hand (Fig. 1). If the object is examined in the palm of the hand most of the light is cut off. Remember also, that it is impossible to obtain good results with a dirty lens. Clean your lens frequently, using a soft handkerchief that will not scratch the glass. Do not carry an unprotected lens loose in your pocket.

To collect plants and animals you will require a certain amount of other equipment. Tobacco tins, especially the flat sort, are very serviceable in themselves, or may be used to contain about half a dozen small glass tubes. These tubes can be bought from apparatus dealers; but empty aspirin tubes serve equally well. If you are at school, persuade your science master to give you short pieces of glass tubing that are of no further use to him. They need be only 1 inch or so long. When the ends are plugged with cotton wool they make excellent containers for small insects, snails, and small dry fruit.

Round tobacco tins and cocoa tins make good live boxes for moths, grasshoppers, frogs, newts, mice, and the like. It is desirable to have air-holes in the lid. These can be simply made by punching them out with a nail. It is best to support the lid on a small piece of wood and drive the nail through the lid from the outside. Then the jagged edges will be inside and not cause you any trouble. A more finished product can be obtained by cutting away the tin from the centre of the lid and soldering a piece of perforated zinc over the hole thus made. This will provide you with an excellent "live box" (Fig. 2).

A supply of tins, with cork fixed to the bottom, in which insects can be pinned, will be necessary. The tins should be between one and two inches deep. Certain throat-pastille tins, or the square "Oxo" tins are quite suitable. Cut a piece of cork sheet (e.g., an old table mat) to the shape of the bottom of the tin. It is best cut with a sharp knife on a board, using a ruler or other straight edge to guide the knife. Then obtain four paper clips of the type that open out (Fig. 2*g*). Punch four holes, one near each corner of the bottom of the tin. Push a paper clip through each hole, and then through the cork, making holes in the cork with the blade of a pair of scissors. Finally bend back the flaps of the clip (Fig. 2*f*). For small tins two clips will be sufficient. If you so desire, you can cover the cork with white paper, sticking it down with gum or flour paste. Flour paste may be made by mixing a heaped teaspoonful of flour with sufficient cold water to form a smooth paste, and then adding a further half a cupful of cold water. Bring it

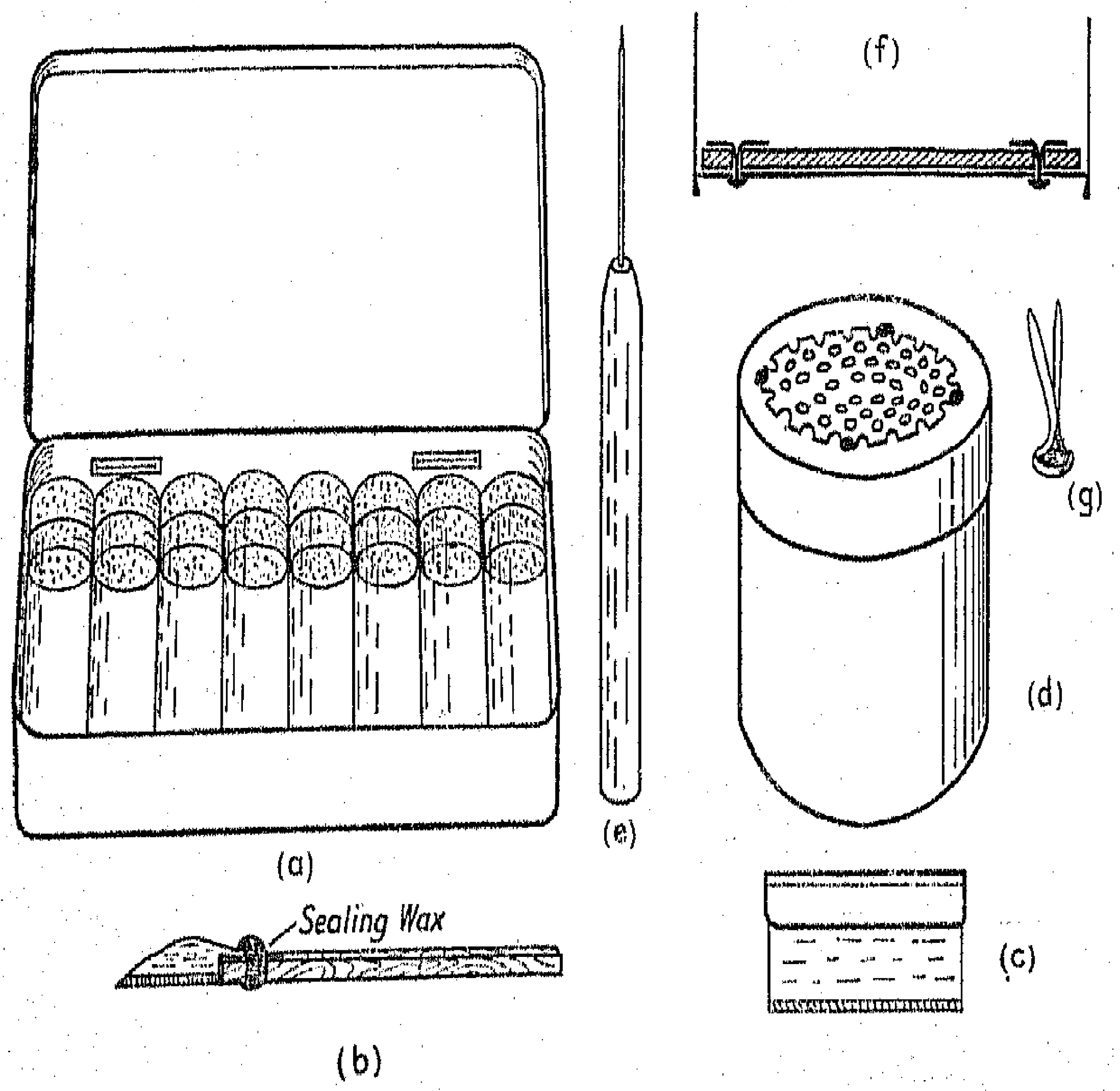


Fig. 2.—Useful equipment: (*a*) a two-ounce tobacco tin used to contain glass specimen tubes; (*b*) a home-made scalpel consisting of a portion of an "Ever Ready" type razor blade, (*c*), fixed into a wooden handle with sealing wax; (*d*) a live-box made by soldering perforated zinc over a hole cut in the lid of a small tin; (*e*) a mounted needle; (*f*) shows how sheet cork may be fastened into the bottom of tins by means of paper clips (*g*).

slowly to the boil, stirring all the time, and then allow the paste to cool before using it.

You will certainly require one or two mounted needles. These are ordinary short darning needles pushed into a wooden handle. Choose a stout needle about 1½ inches long. Make a handle about 3 inches long and as thick as a pencil, from some soft wood such as pine. Trim it with a knife, sandpaper it smooth, and then make a hole up the centre with a drill or very thin nail. Gripping the needle with a pair of pliers, push the head of the needle into the handle. When not in use, the point of the needle should be protected, so that it will not become blunt.

A razor blade, one of the "Ever-ready" type that has a stiff piece of metal opposite to the cutting edge, is very useful. It should be kept in a small tin and covered with cotton wool to protect its edge. To make a handy scalpel (dissecting knife) take one of these blades and with a pair of pliers break off triangular pieces to include a portion of the cutting edge. The most suitable of these pieces can then be inserted in a cleft made in a wooden handle and fixed with sealing wax (Fig. 2*b*).

To collect plants [illegible] to keep them fresh for a day or two, you will require a vasculum—a [illegible] with a tightly-fitting lid. A 1 lb. cocoa tin will serve, but a larger tin is better. A square biscuit tin is best of all.

Jam-pots are indispensable for keeping live creatures. If they are used for pond creatures, they should be covered with a suitable piece of glass. If used for insects and the like, cover the top with a piece of cloth and hold it in position with an elastic band or a thick piece of string. (I advise thick string because it is easier to untie than thin string).

For rearing-cages, much can be done with jam-pots and cardboard boxes. Old buckets and basins sunk into the garden and filled with water make quite serviceable "ponds" in which you can grow certain water plants and keep a wide variety of the smaller pond animals all the year round. Shallow ponds, however, are liable to freeze solid in very frosty weather, and the container will crack if it is of earthenware or glass. When you make a pond, place garden soil or sand in the water and stir it well. It may take a week or so to settle, but it is essential if the pond is to be really successful. Make your pond in a shady place where it will not be exposed to strong sunlight all day long.

For making any sort of collection of insects, a killing bottle is indispensable. A jar with a wide mouth and a screw-on top will serve. I use a honey jar (1 lb. size). The lid must be air-tight. To ensure this, cut a disc of fairly soft cardboard to fit snugly inside the lid. Before fitting the disc, place it in some candle wax melted in a tin lid. After the cardboard has become well soaked, remove it and allow the wax to harden. Then fit the disc inside the screw-on lid of the jar.

The killing agent for the jar can be crushed laurel leaves. These are best gathered in May. Choose the young leaves, which are a light yellowish green, and chop them up *as finely as you can.* Pack them tightly into the bottom of the jar, ramming them in with a piece of wood. There should be enough leaves to reach about half-way up the jar when they are tightly packed. Next, place two thicknesses of blotting-paper over the leaves, and the jar is ready for use. If you keep the lid on, the bottle will retain its strength for many months. You must make sure that you obtain genuine Cherry Laurel. Rather similar plants with large yellow blotches on their leaves will not work at all. I have made a drawing of a Cherry Laurel twig with leaves in Fig. 3. The leaves are retained on the plant throughout the winter. Cherry Laurels are common enough in towns, often being planted as hedges, but they are less common in country districts. Special killing fluids that are harmless to humans can be obtained cheaply from dealers. To

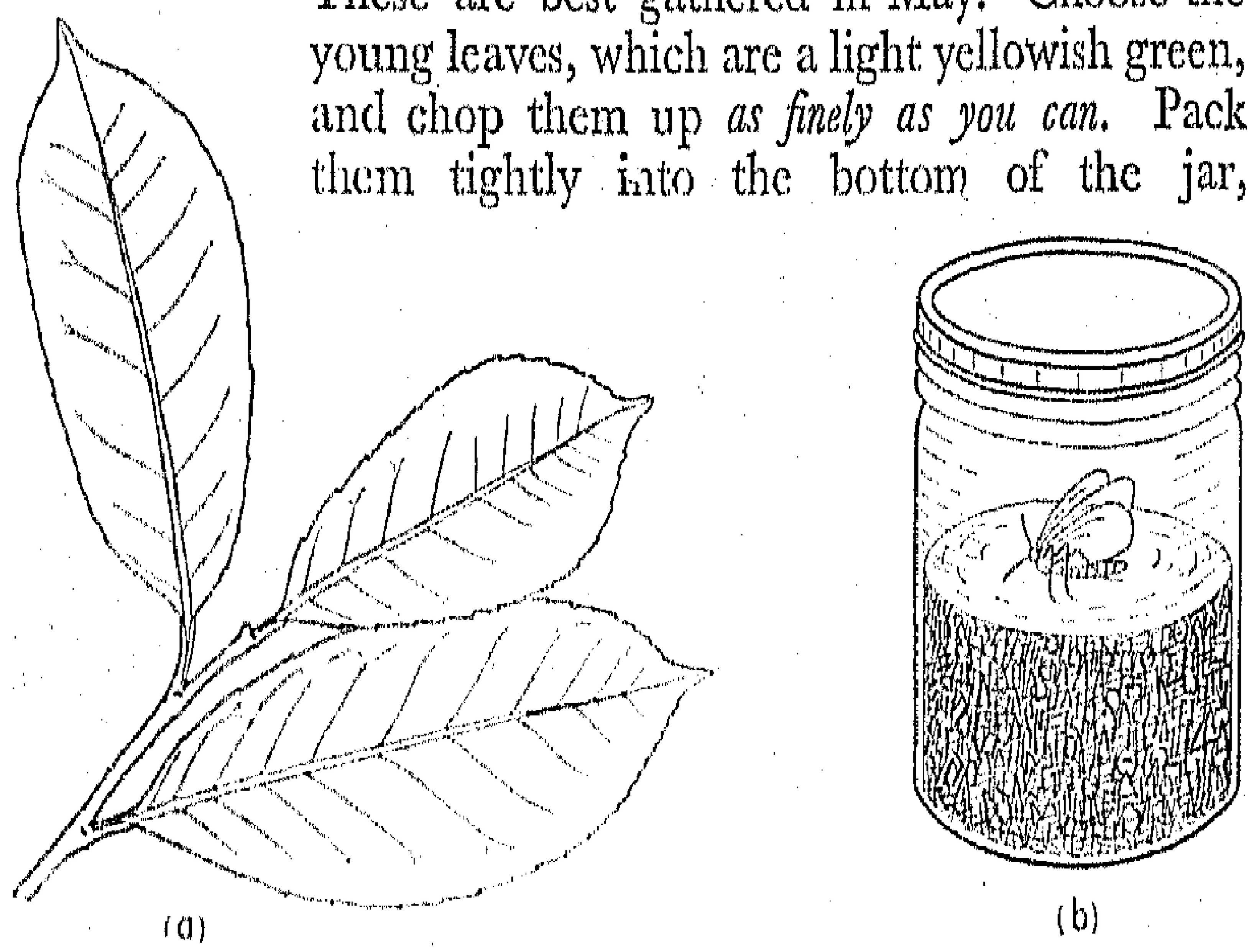


FIG. 3.—(*a*) a sprig of Cherry Laurel; (*b*) a killing bottle made from a honey jar half filled with finely chopped and tightly packed Cherry Laurel leaves.

use these a few drops are added to a wad of cotton wool in the bottom of the bottle; but the killing bottle will have to be recharged at frequent intervals, especially on hot days.

Setting-boards (Fig. 4), though not essential, are necessary if certain types of insects are to be displayed to the best advantage. They can be made from strips of cork sheet covered with glossy paper.

A water net, and a net for use on land, you must have. The water net can easily be made from thick iron wire—copper wire is too soft. It need only be a circular or square hoop, a few inches in diameter. A square pattern is probably best; one with sides measuring 4 inches is very suitable. The bag must be made of stout calico but need be only 2 or 3 inches deep. When the net is in use it is best tied to a stout wooden handle, 3 or 4 feet long.

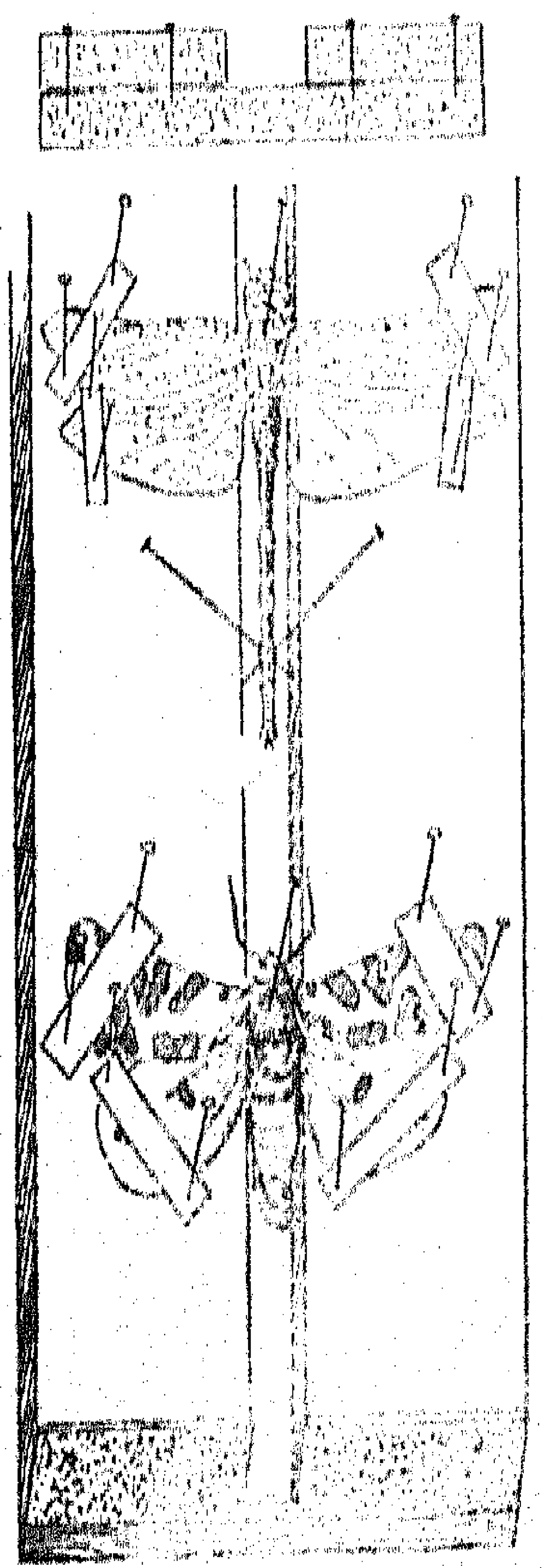


Fig. 4. Method of making a setting board from strips of cork, or balsa wood. Note the centre groove. *Above,* cross section; *below,* viewed from above.

A net for use on land is not so easily made. A wire frame is of little use, as the diameter should be about 18 inches; otherwise it is very difficult to catch flying insects in the net. If you can possibly afford to buy a folding net I strongly advise you to do so. Quite a useful net for sweeping about in grass and undergrowth can be made by sewing a bag on to the frame of a discarded tennis racket. The bag should be about 18 inches deep. Such a net, however, is hardly wide enough to catch the more powerfully flying insects.

Finally, you will require a quantity of insect pins. Ordinary pins are too thick. You will have to purchase half an ounce of mixed black insect pins, and these will last you quite a long time.

CHAPTER TWO

Finding Names

BEFORE we can go much further we shall have to use a number of scientific terms, especially the scientific names of plants and animals. You may find the pronunciation of some of these difficult at first, but that is largely because the words will look strange. You must learn to pronounce and use them as you do other long words such as hippopotamus and rhinoceros. Once you have heard the scientific names spoken, they are just as easy as these, and many a good deal easier. They soon become part of the fun of Natural History. Scientific names will be printed in italics and I shall attempt to give you some idea of the pronunciation of each one the first time it occurs.

As soon as you begin to take an interest in living things, it becomes clear that there are very many different forms indeed. On a country walk, notice the variety of flowers, trees, grasses, ferns, and mosses. Go for a walk through the woods in autumn, and see all the different types of toadstools growing both from the ground and out of tree trunks. In a town garden or park it is very easy to see a dozen or so different kinds of birds in the space of an hour, as well as innumerable different kinds of insects.

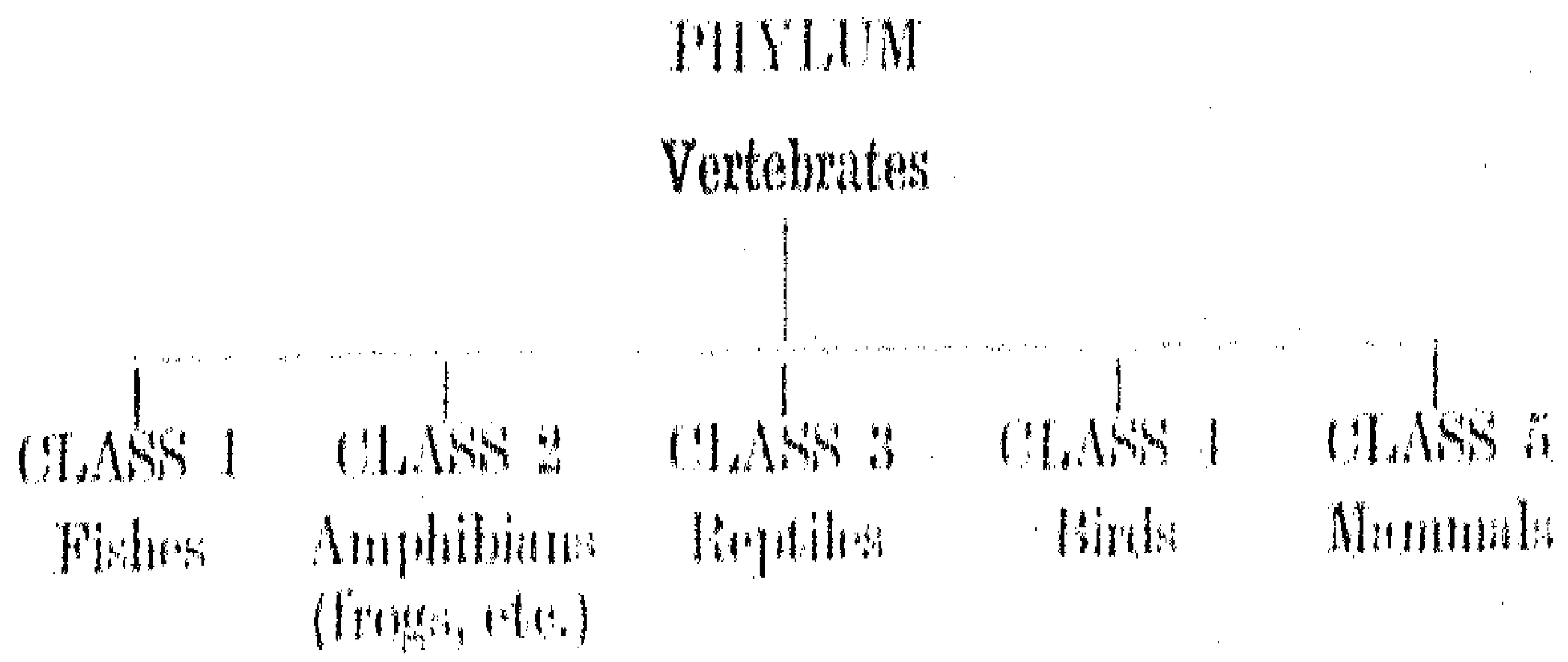
But soon you will realise that among these different kinds of living things there is only a small number of definite patterns; and with some of these patterns you will already be familiar. It is, for example, quite easy to say whether a particular animal is a bird or a fish, or whether it is neither of these. In other cases, although you may have a vague feeling that a number of specimens are very much alike, it is difficult to be sure that in fact they are all alike in the same way that all birds are alike. You may think that because houseflies, spiders, and woodlice resemble one another in having a hard covering on their bodies and in possessing a number of many-jointed legs, they all belong to one pattern—the pattern we call insects. A biologist, however, would tell you that of these three, only the housefly is an insect. He would agree that the three types have a general resemblance and because of this they are regarded as belonging to a main pattern called the *Arthropods* (ar-throw-pods). Such a main pattern is called a Phylum (fy-lum). The members of it can usually be arranged in smaller groups, each having its characteristic features. Insects are one such group, having three pairs of legs and, as a rule, wings. Spiders belong to another of these smaller groups called *Arachnids* (a-rack-nids). They have four pairs of legs. The woodlouse is a member of a third group, the *Crustaceans* (krus-tay-she-ans), and possesses many pairs of legs besides two pairs of "feelers".

Altogether there are about twenty main patterns of living things. One such pattern (or phylum) consists of all the backboned animals—that is the fishes, amphibians (frogs, toads and newts), reptiles, birds, and mammals (the mammals including dogs, cats, cows, man himself, and all other forms that have a coat of hair). Another main pattern, the phylum *Mollusca* (mol-lusk-a), includes snails, slugs, and octopuses; while the trees, flowers, and grasses, belong to another phylum.

A phylum, therefore, consists of a number of plants or animals which, although not exactly the same, are yet built upon some general plan that is different from the plan of any other phylum, just as all bicycles are very similar to one another and quite different from any other kind of machine. But just as you could divide a collection of bicycles into certain types resembling one another in the shape of their handlebars, the kind of brakes, etc., so too can a phylum be divided into smaller groups. The members of each of these smaller groups resemble one another more closely than they resemble the other members of the phylum.

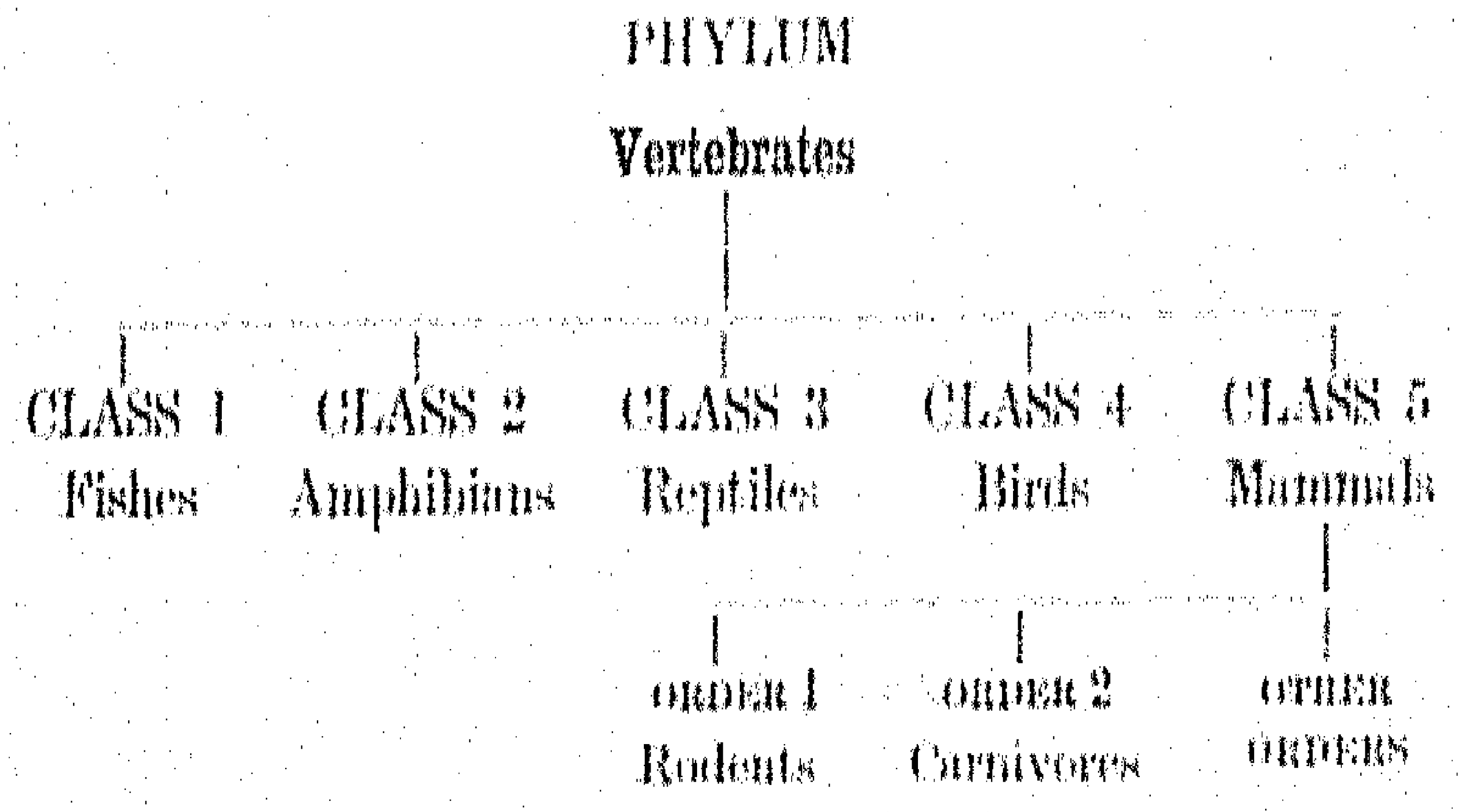
Thus, although fishes and birds are both in the *Vertebrate* phylum (because they have backbones) yet they are placed in separate Classes of the phylum. In the same way all mammals, by possessing a coat of hair, resemble one another more closely than they resemble reptiles (e.g., snakes, lizards, crocodiles, and tortoises) which are covered with scales. So mammals are placed in another class, and reptiles in a fourth.

Proceeding in this way we can divide each phylum into smaller groups called classes. The phylum of vertebrates is divided into five classes:

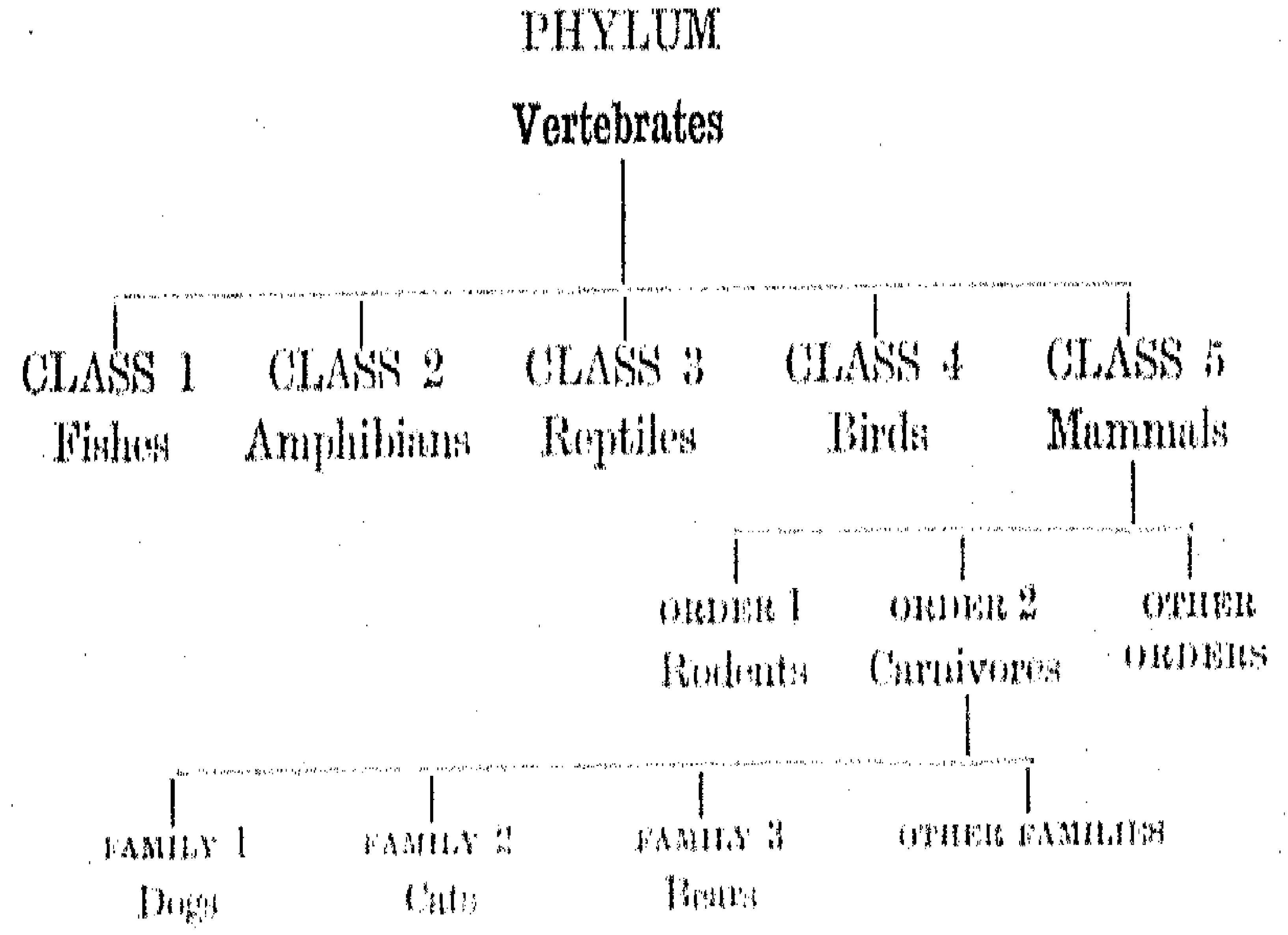


In their turn the classes can be divided into smaller groups called Orders. If we consider the mammal class, there are obvious differences between monkeys and mice, cats and cows, wolves and rabbits. Yet at the same time, there are also obvious close resemblances between cats, dogs, bears, wolves, weasels, and stoats—for example in the nature of their feet and teeth. These latter animals, together with some others, are placed together in a smaller group called an order, in this case the order of *Carnivores* (kahr-niv-ors). Other groups of mammals that resemble one another are placed in other orders, e.g., the gnawing animals such as mice, rabbits, rats, squirrels, and guinea pigs, are placed in the order of *Rodents*.

So a phylum is divided into classes, and the classes are divided into orders. Taking the Vertebrate phylum again, we have:



Now once more it is clear that in the order of Carnivores there are further subdivisions possible. The dog-like animals form a group distinct from the cat-like animals, and both differ from the bears or the weasels. To express this, we further divide each order into Families. The order of Carnivores is divided into the dog family, the cat family, the bear family, and others that I will not mention here. (The other orders, of course, are each divided into families in the same way.) The scheme now looks like this:



Even the families contain many obviously different types of animals. The cat family includes, amongst others, the lion, the tiger, the leopard, the domestic and the wild cats, and the cheeta. So the family can be yet again divided, by further application of the fact that certain members resemble one another more than they resemble the rest. In this way we arrive at smaller groups called GENERA (jen-era—a plural word, the singular of which is *genus*). In the cat family there are only two genera. One of these, the genus *Cynælurus* (sy-nee-lure-us) contains only one animal, the cheeta or hunting leopard. The other genus is called *Felis* (fee-lis), and includes such animals as the ordinary cat, lion, tiger, and leopard. Now if you had several hundred mixed animals all belonging to the genus *Felis*, you would be able to sort them out into a few groups—lions, tigers, cats, and so on—and you would be fairly certain that each animal in a particular group was the same *kind* of animal as the others in that group. The domestic cats might differ among themselves in colour, in length of fur, and to some extent in shape, but still you would be quite sure that they were cats, especially if you compared their teeth and other characteristics in detail. So too, the tigers might vary a little in size or colour, but they would be quite unmistakably tigers. Furthermore, the cats would be able to breed together to produce kittens more or less like themselves, and the tigers would be able to have cubs which in time would grow up into tigers like their parents.

When we have a group of animals or plants which everyone will agree are the same as one another, we say these animals or plants belong to one SPECIES. The members of a species, besides being very like one another, will breed together to form more members like themselves. Animals or plants which belong to different species will not as a rule breed together, or if they do, the offspring are unlike the parents. Thus, at the zoo, lions have occasionally been bred with tigers. The offspring, called tigrons, are not very like either parent. Similarly, if a horse breeds with a donkey the offspring produced is a mule, an animal quite distinct from either a horse or a donkey.

To sum up all this, let us look at the position of the lion in the phylum of vertebrates:

PHYLUM —Vertebrate
↓
CLASS —Mammal
↓
ORDER —Carnivore
↓
FAMILY —Cat
↓
GENUS —Felis
↓
SPECIES —Lion

Now there are very many different animals and plants in the world and many scientists in different countries studying them. Consequently, it is necessary to have such a system of naming the species that everyone throughout the world will be quite clear which particular kind of plant or animal is meant when its name is given. The scientific way to name a plant or animal is to give it a double name—a kind of surname and christian name if you like—made up of the name of the genus to which it belongs followed by the name of the species. Thus the lion is called *Felis leo*. That means it belongs to the genus *Felis* and is the species *leo*. Notice that the name of the genus begins with a capital letter, while the species name is written with a small initial letter. The scientific names of other members of the genus *Felis* are

Tiger—*Felis tigris*
Leopard—*Felis pardus*
Tame cat—*Felis catus*
Wild cat—*Felis sylvestris*

You can see how this system of naming will help to prevent mistakes. If you are writing about the cat, you may be referring to either the wild cat (*Felis sylvestris*) or the tame cat (*Felis catus*). If you give the scientific name there is no doubt which is meant. Even if it is a tame cat that has gone wild, it would still be *Felis catus*, having merely changed its habits but not its structure. As a further illustration, I may mention that the animal which is commonly called the lion in America is the animal we call the puma. Its scientific name is *Felis concolor*. If, when referring to the lion, writers stated the scientific name of the animal they intended (either *Felis leo* or *Felis concolor*) no mistakes would be possible. By far the most important application of this system, however, is to those many animals and plants which have no common name. In these cases we *must* use the scientific name. We shall come across this use in Part II of this book.

How to use "Keys"

To find out the name of a plant or animal that he has collected, the naturalist may make use of "keys". Keys are usually made by experts on the different groups, and are so constructed that by answering correctly the questions asked about the specimens, you will be able to find their names.

Most keys are rather difficult to use until you know a good deal about the structure of living things; and in many cases a microscope is necessary to see tiny structures. In this book it has been possible to give you only a few simple keys. If you become very interested in Natural History, you will have to obtain other books written specially for the purpose of naming the species in particular groups.

To show you how to use a key, I have constructed one that would enable you to tell which one of five common objects (a pen nib, a rubber, a penholder, a pencil box and a pencil) you had, assuming you did not know its name. Here is the key:

1	Made at least partly of wood	3
	No wood at all	2
2	Made entirely of metal, rather pointed at one end	PEN NIB
	No metal present—rather soft to the touch	RUBBER
3	Shape rectangular, with a moving lid	PENCIL BOX
	Shape long and thin—no moving parts	4
4	Fitted with a metal holder at one end	PENHOLDER
	No metal at all	PENCIL

Remember that you are not supposed to know the name of any of these objects. Suppose you wish to use the key to find out the name of the pencil. You proceed as follows.

First, notice that the clues in the key are arranged in pairs which are bracketed together, and each pair has a number in front of it. You start with the first pair, and have to decide which one of the two statements given there applies to the object you wish to name. Is it "made at least in part of wood", or is there "no wood at all" in it? Obviously it (i.e., the pencil) is made partly of wood. At the end of the line "made at least partly of wood" the number 3 occurs. This means that now you must go to the pair of statements marked 3, leaving out altogether the pair marked 2, for they do not apply to your object. (The clue "no wood at all" leads to them, and your object *has* some wood in it.)

Again at 3 there are two statements. Which applies? Is your object rectangular in shape with a moving lid, or is its shape long and thin without a moving part? Obviously it is the second. The number 4 occurs at the end of the line "Shape long and thin—no moving parts", so you pass on to the pair of statements numbered 4. Is the object fitted with a metal cap at one end? No. It has "no metal at all". At the end of this line is its name. It is a pencil.

This key is of no practical use to you, because you already know the names of all the objects. But it would be of use to someone who did not know the names. That is what Natural History keys are for, to enable you to find the names of plants and animals you do not already know.

The keys to the groups of plants and animals are not so simple as the one we have just used, and it is very easy to go wrong with them, so you will have to learn to observe the characters of specimens very closely. If you do go wrong at any point, you will generally soon find out, because in later pairs of characters you will probably find that the specimen fits neither of these clues. Then you have to go back and start again.

You will find that using keys is great fun, rather like the game "Animal, Mineral or Vegetable". It must be repeated that if you become really interested in Natural History and need more keys, you will find that there are special books that give them for most of the groups—though for some groups (e.g., the two-winged flies) complete keys have not yet been constructed.

PART II

CHAPTER THREE

Flowers

THE most familiar group of the plant kingdom contains all those plants commonly known as flowering plants. I shall take the TULIP as a first example.

The Tulip—A Monocotyledon

A tulip should be obtained for examination as you read the description below. Tulips are flowering in the garden from April to early June; the best course is to plant a few bulbs in October and leave them to come up in spring in the normal way. Tulips will also grow quite well indoors in pots or bowls of bulb fibre, which can be bought quite cheaply. During November and December the pots are best kept in a cool dark place such as the bottom of a cupboard or a cellar, but the bulb fibre must be kept moist.

The drawings in Fig. 5 will help you to understand the structure of a tulip flower. The coloured parts usually called petals are on the outside. Before the flower opens, you will see that these are green and serve to protect the inner parts. They become coloured gradually, as the flower opens. There are six petals all together and it is easy to see that they are arranged in two whorls (or rings), three in the outer ring and then three in an inner ring, so arranged that the inner petals fill in the gaps between the petals of the outer whorl. In this way the whole structure forms a kind of cup which opens when it is warm and closes when it is cold.

Remove three of the petals from one side The inner parts of the flower will now be visible and you will see the six (really two whorls of three) stamens, as shown in Fig. 5 (*a*). Each stamen consists of two parts, a rather broad flattish structure that is fixed at one end to the top of the stem and carries another structure, the pollen box or *anther*, at its free end. The anther may be variously coloured. If the tulip has been open some time, the anther will be seen to be split along its edges and to be covered with a fine dust which, under the hand lens, you will see to consist of very tiny grains. This is the pollen. When looking at it under a hand lens, do not forget that you must have *plenty of light* falling on it (see p. 4). You will probably find that the anthers will swivel round on the stalks of the stamens. Make a drawing of the tulip with its three petals removed. Then make another of a single stamen. A drawing must be labelled, and to make the drawing look neat, it is a good plan to keep all the labelling lines (guide lines is their correct name) parallel to the top and bottom of the page, and to *print* the names of the structures you wish to indicate. Make sure that each guide line really does end where you intend it to end. Remember also that guide lines should always be ruled, never drawn in carelessly. Finally, avoid shading your drawings more than is absolutely essential.

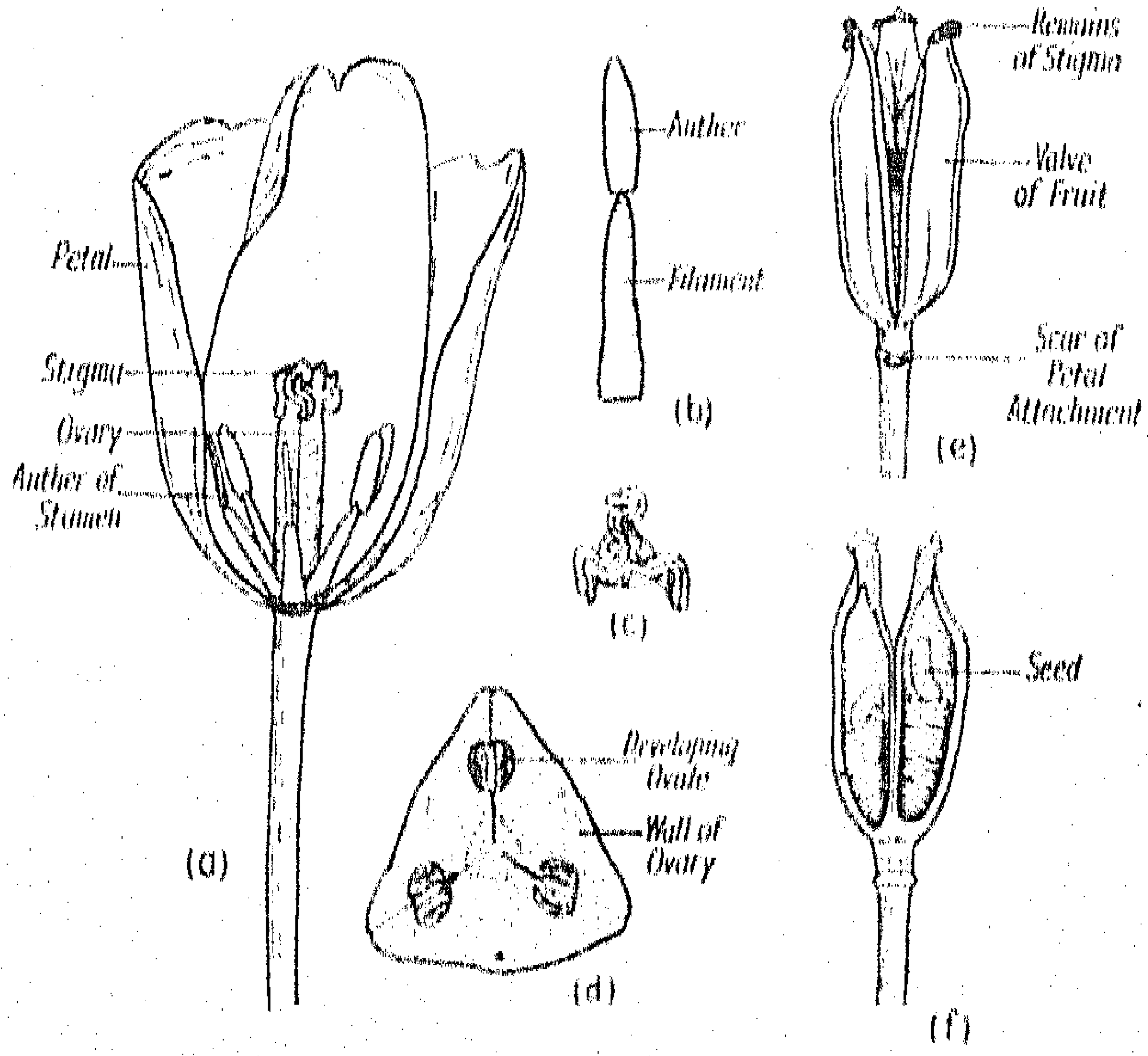


Fig. 5.—(*a*) a tulip flower with three petals removed from one side, × ½; (*b*) a single stamen, × 1; (*c*) the stigma drawn from above to show its three lobes, × 1; (*d*) cross section of the developing fruit, × 2½; (*e*) the ripe fruit, beginning to open, × ½; (*f*) the same with one valve removed to display the seeds, × ½.

Now remove all the petals and stamens from the tulip. You are left with a single rather fat central column, called the *pistil*. In the tulip it consists of only two parts. The bottom part, which is a three-sided column, is called the *ovary*. At its top, the ovary is crowned with a yellowish structure having three lobes which overhang the sides of the ovary. This structure is called the *stigma*, and if you examine it very closely you may be able to see pollen grains adhering.

The task of the flower is to provide for a new generation of tulip plants by forming seeds, which are young plants inside a protective coat (see p. 223). Thus the flower is the reproductive organ of the plant, and every part of it has an important job. The ovary contains structures called ovules which themselves contain female reproductive units or "eggs". An ovule is capable of developing into a seed, but before this can occur the "egg" inside the ovule must unite with a male reproductive unit. These are produced by pollen grains that have reached the stigma, usually, in tulips, having been carried there by insects. Each pollen grain on the stigma puts out a fine tube that grows through the tissues of the ovary until it reaches an ovule. Then the male unit which the tube contains at its tip unites with the female unit of the ovule. This union is called fertilisation, and it is the essential act in all forms of sexual reproduction, being to all intents and purposes the same both in animals and plants (see p. 282). The brightly coloured petals serve to attract the insects that transfer pollen from the stamens to the stigmas. The petals also protect the stamens and pistil from frost and rain.

Now with a razor blade or sharp knife cut across the column of the ovary and examine the surface. This cut surface is called a cross section of the ovary. Under the hand lens (remember—*plenty of light!*) it will look like Fig. 5(*d*). There will be three groups of developing ovules, one group at each corner of the triangle. If the tulip you have cut was a very young flower it will not be easy to see very much, but in older tulips, especially those whose petals have fallen, you will be able to see that there are two seeds in each group, and each seed is connected to the centre by a fine stalk along which food is brought from the tulip plant.

If you have several tulips growing, it is a good plan to brush some pollen from the stamens on to the stigmas and allow the plants to go on growing, so that you may examine a fresh ovary every two or three weeks. In that way you will see the ovules gradually grow bigger and develop into seeds. The ovary, too, will become swollen. Leave at least one ovary to become ripe. It is then called a fruit—i.e., a fruit is a ripe ovary with its seeds, even though it is not tempting to eat as is a plum, tomato or gooseberry. The tulip fruit is a dry fruit, and, when ripe, it splits along its three edges and the seeds can be easily shaken out. Tulip ovaries take several months to become quite ripe, but they frequently fail to develop in the garden.

If you collect the seeds when they are ripe (when the ovary begins to split) and sow them in the garden, they will grow into new tulip plants, but it will be several years before they will flower. If you have patience to do this, you will see each seed push up a single slender first leaf like an onion or grass seed.* This will go on growing and gradually a small bulb will form under the ground. When the new plant ultimately flowers, you will probably find that the flower is not the same in colour and shape as the one with which you started.

Now take a tulip leaf, hold it up to the light, and look through it. You will notice that there is a number of faint lines running along it, more or less parallel to one another. These are the veins through which food and water are carried through the plant. We have seen that the parts of the tulip flower are arranged in threes and that the veins of the leaf are more or less parallel to one another. These are the characters that enable us to recognise members of one of the big groups of flowering plants. This group is called the *Monocotyledons* (mon-o-kot-il-ee-dons) and its members have only one seed leaf (or cotyledon) in the seed (see p. 224).

Another group of flowering plants has the veins in the leaves in the form of a network and does not have the parts of the flowers arranged regularly in threes. Often they are in fours or fives. These plants are called *Dicotyledons* (di-kot-il-ee-dons) because they have two leaves in the seeds. For shortness, naturalists speak of these two groups of flowers as monocots and dicots.

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* What is usually called a seed of grass is actually a fruit containing only one seed, i.e., it is a complete ripe ovary.

Examine as many plants as you can, looking both at the flower parts and at the leaves, and decide whether they are monocots or dicots. You may come across a few doubtful ones, but this is because the real difference between monocots and dicots is the number of seed leaves (cotyledons). This character is often not easily determined, especially in small seeds, so we shall not deal with it.

The Wallflower—A Dicotyledon

As an example of a dicot take the **Wallflower**. The structure is shown in Fig. 6. Unlike that of the tulip, the flower bud is protected by four green *sepals* which, although they may become coloured when the flower opens, remain quite distinct

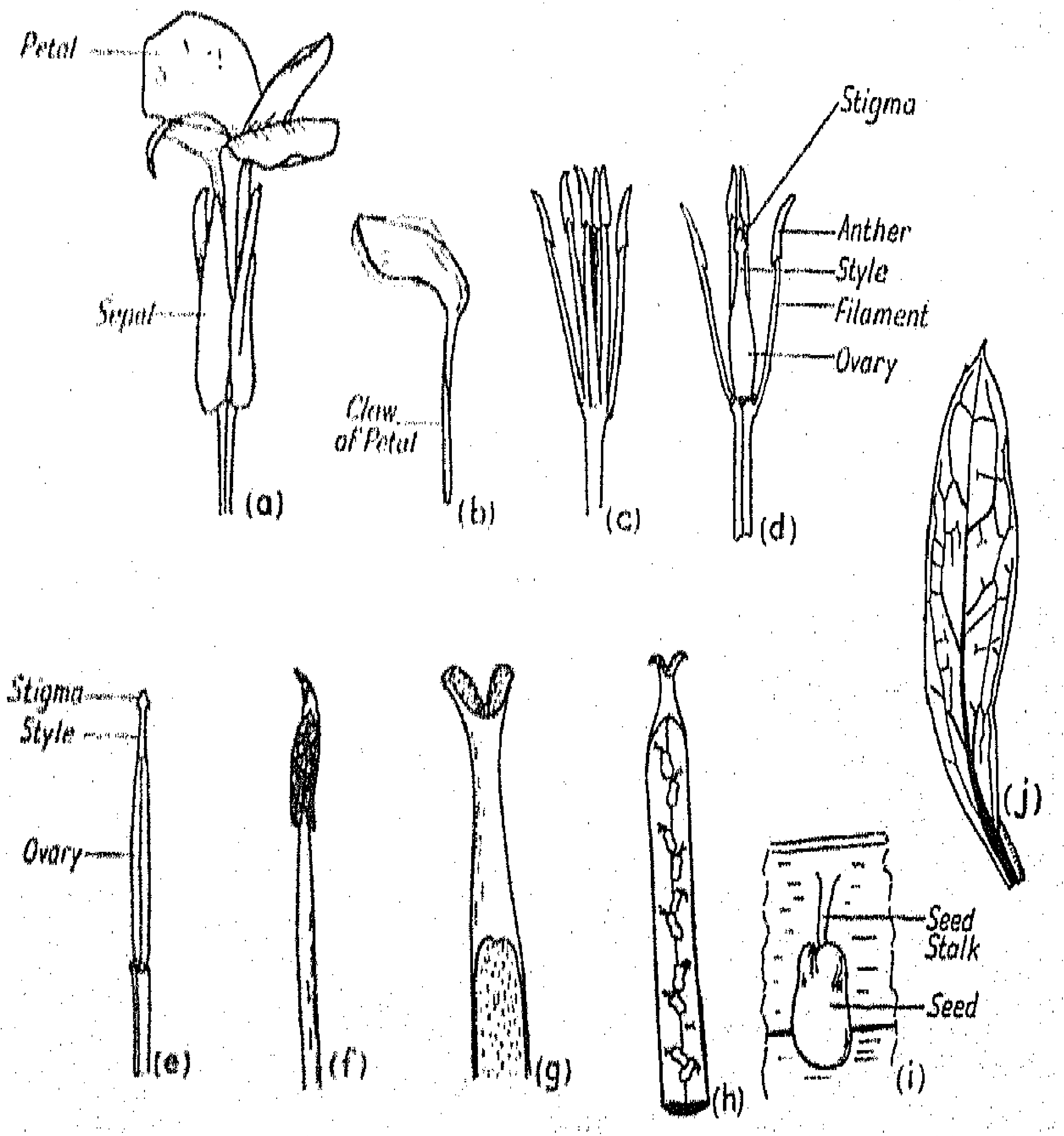

Fig. 6.—(*a*) a single wallflower bloom, ×1½; (*b*) a single petal, detached, ×1½; (*c*) the flower with the sepals and petals removed, ×1½; (*d*) the same with two stamens removed, × 1½; (*e*) the pistil, ×1½; (*f*) a single stamen, × 3; (*g*) the tip of the pistil, to show the bilobed stigma, ×5; (*h*) a portion of a young fruit, split open to display the seeds, ×1; (*i*) a single seed attached to the fruit wall, ×5; (*j*) a leaf, ×½.

from the brightly coloured and larger petals. The sepals bulge downwards at the lower end to form a shallow pocket, in which you can often see a clear liquid which is sweet to the taste. This liquid is nectar, and it is eagerly sought by certain insects.

There are four petals. Each consists of a broad platform which, near the centre of the flower, bends sharply at right angles and is continued downwards as a much narrower stem or claw. The bottom end of the claw is attached to the upper end of the flower stalk. The four petals, together with the claws of the four petals, form a kind of tube. Inside this tube are the stamens and pistil.

There are six stamens, but instead of being arranged in two whorls of three as they are in the tulip, two stamens which are a little shorter than the others are arranged opposite to one another, while the remaining four inner stamens are arranged in two pairs (Fig. 6*c*). As in the tulip, the stamens bear anthers at the top and these split open to set free a mass of pollen grains.

Nectar, which is a weak sugar solution, is produced by glands at the bottom of the tube formed by the petals and sepals. With your hand lens you will be able to see the *nectaries*, as these glands are called. They are dark green patches, often sticky in appearance, visible where the two shorter stamens join the stem. To reach this nectar, insects have to push their tongues right down the tube, so that only insects with long tongues (e.g., butterflies and bees) can reach it.

The pistil is unlike that of the tulip. It is long, and, in young flowers, rather round in cross section. Between the ovary and the stigma is a short piece called the style. No style was visible in the tulip. The stigma in the wallflower is split into two pieces or lobes.

Take a wallflower to pieces and compare its structure with the drawings in Fig. 6.

If you have a branch of a wallflower plant bearing several flowers, you will find that the youngest flowers are at the top of the stem. A little lower will be flowers whose petals are dropping, and lower still all that remains will be the pistils of flowers. In these the ovary will already have begun to enlarge. To examine the structure of the fruit (as the ripe ovary is called, remember), you may have to wait a few weeks, leaving a wallflower plant in the garden after the flowers have faded.

When you have a large fruit, say 1–2 inches long, cut it across as you did the fruit of the tulip. You will see that there are only two double rows of seeds and these are attached to the outer walls of the ovary, not to the centre as they were in the tulip. Along the centre of the ovary is a longitudinal partition dividing the cavity of the ovary into two separate chambers. With a mounted needle you will be able to strip off one side of the ovary lengthwise, and uncover the seeds of one side (Fig. 6*h*).

Keep a watch on the growing plant for a few more weeks and you will see the fruit ripen and become dry. Then it will split at the bottom and two flaps (called valves) will begin to curl up to uncover the dry seeds and central partition of the ovary. The seeds will then be shaken out and blown away by the wind, in time to grow into new plants. When the fruit is ripe, you can collect the seeds, sow them, and so obtain new wallflower plants ready for next year.

A leaf of the wallflower is drawn in Fig. 6 (*j*). At first, when you look at one, the veins may not be visible; but if you hold the leaf to the light and look through it, the veins stand out as lighter lines. You will see that they form an irregular network quite unlike the parallel veins of the tulip. Your leaf may not look exactly like Fig. 6(*j*) because wallflower leaves vary a little among themselves.

If you now examine a number of different flowers, you will find that they differ in many respects from the tulip and the wallflower, but in each one you should have no difficulty in recognising the various structures. Sometimes the petals will be firmly joined together to form a tube, as in the snapdragon, bluebell, primrose, and foxglove; sometimes the pistil will consist of many separate pieces (called carpels), as in the buttercup, strawberry and blackberry. Often, as in the bluebell and primrose, the stamens will be joined at their bases to the petals. In some flowers, e.g., lupins, peas, and many others, the stems of the stamens may be joined together to form a tube inside which is the pistil (Fig. 8*d*), while sometimes, as in the daffodil, snowdrop, and gooseberry, the ovary is below the petals and stamens.

Dandelions and Daisies—Composite Flowers

You may at first be puzzled by members of the COMPOSITE group of flowers. This group includes dandelions, chrysanthemums, asters, dahlias, thistles, and all the daisy-like flowers.

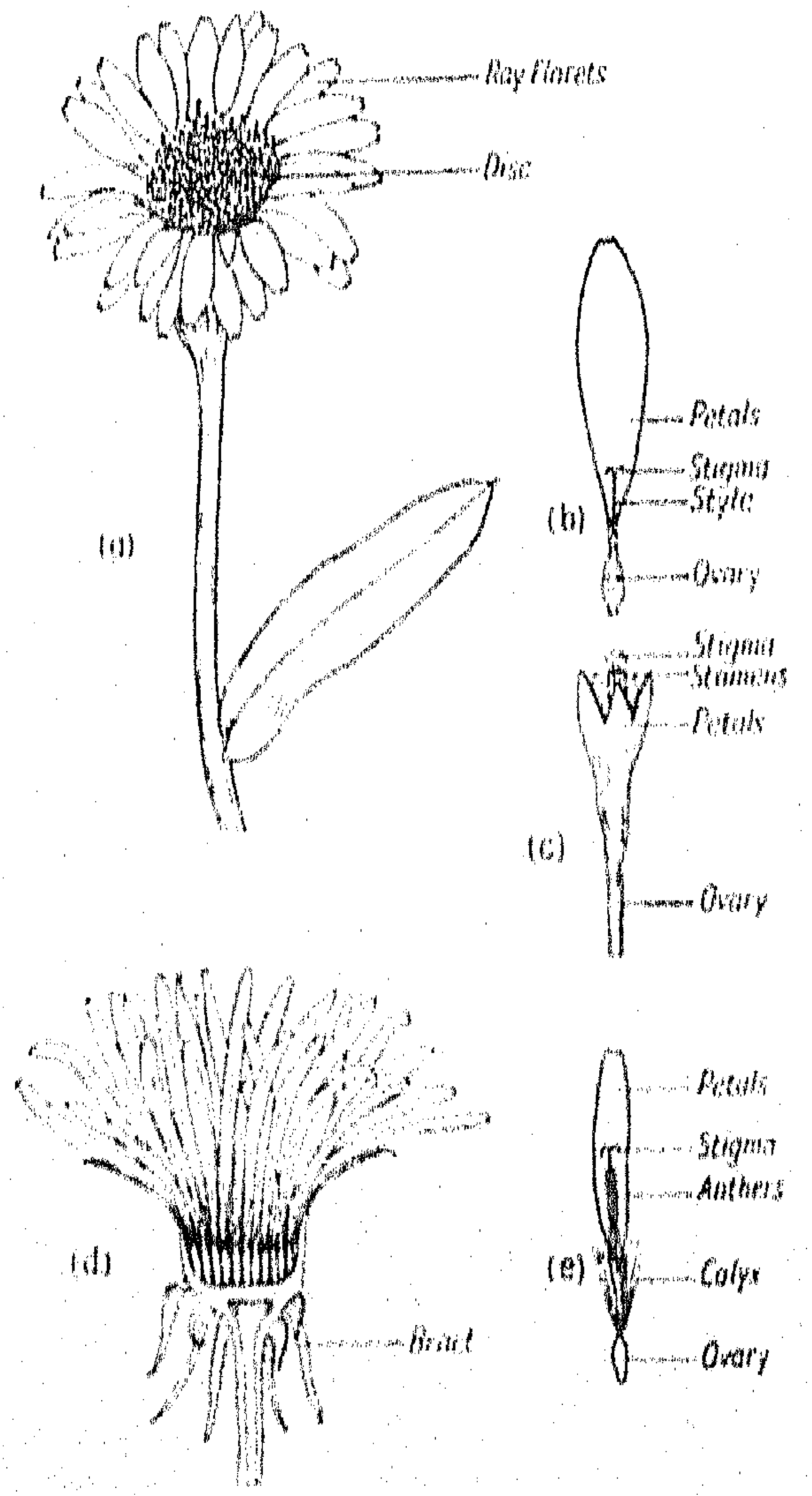

FIG. 7.—(a) a garden marigold, ×½; (b) a ray floret, ×1½, and (c) a disc floret, of the marigold, ×3; (d) a section through a flower head of dandelion, ×1½; (e) a single floret of dandelion, ×1½.

In all of these plants, what appears to be one complete flower (e.g., a dandelion or a daisy) is actually a head of many tiny flowers packed tightly side by side. The apparent petals of a dandelion or daisy are thus not petals at all but are complete flowers and are called *florets.* If you pull one of these "petals" from the flower head of a dandelion you will be able

to see the yellow strap-shaped structure that represents the petals which are all joined together, the two-branched stigma, and the stamens which are quite thin and joined together by their anthers so that they form a closed ring or collar around the style. At the very bottom of the floret is the ovary. Fig. 7(*e*) should make this clear.

In dandelions and some other Composites all the tiny florets are the same; but in the daisy-like Composites there are two kinds of florets, outer strap-shaped ones which have no stamens, and smaller inner ones—the disc florets—which do have stamens and whose petals form a tube with five fine teeth. These disc florets make up the "eye" of a daisy, but in this plant are rather small. They are best seen in a sunflower or dog-daisy. Fig. 7 (*a–c*) shows the structure of a garden marigold.

There is no purpose in my describing all the many forms of flowers; you must obtain them and see for yourselves. It is a good plan, when investigating the structure of a new flower, to cut it down the centre with a sharp razor blade. To do this, hold the flower fairly firmly between thumb and forefinger of

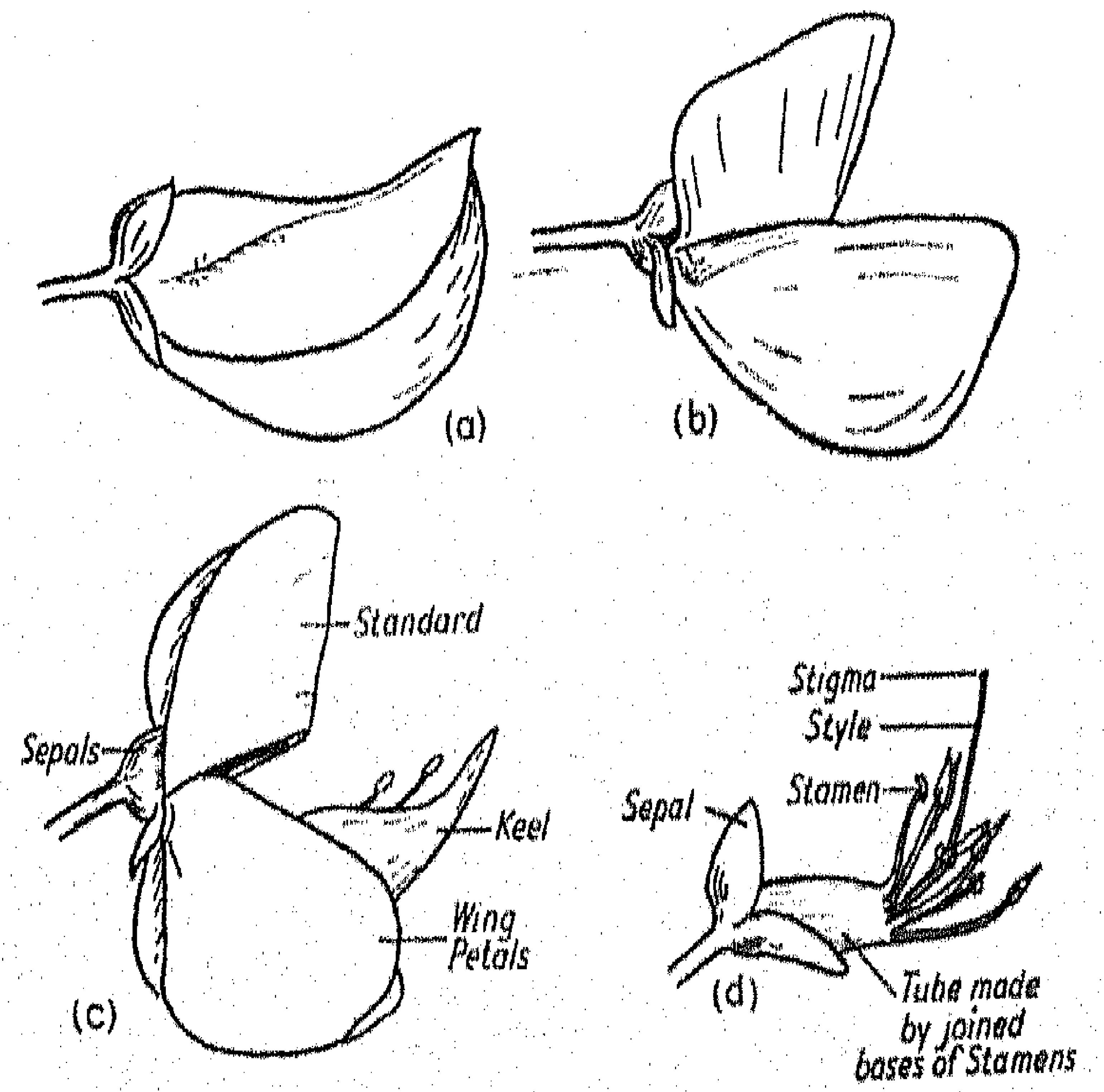

FIG. 8.—The flower of the lupin: (*a*) a young flower; (*b*) an older flower; (*c*) the same with wings and keel depressed; (*d*) a flower with the petals removed. (All ×4.)

your left hand, with the stalk end uppermost; start cutting at the end of the stalk and continue through the flower until you have two halves. Usually one of these parts will show the structure very well.

When a number of flowers have the same general plan of structure we place them together in a group we call a Family. The daisies, dandelions and such similar plants, as we have seen, are placed in a family called the *Compositæ* (com-poz-it-ee). The **Pea Flower** family (*Leguminosæ*)—(le-gew-min-o-see) also has an easily recognised general plan.

The Pea Flower Family

In members of the Pea Flower family (Fig. 8) there is usually a sharp bend where the flower joins the flower stalk. Next come the sepals, which are joined together and may form only a quite small ring. The petals are usually very showy and are five in number, arranged in a special manner. The biggest petal is at the top of the flower, and is quite broad, often with a notch at its tip and a groove down its mid-line, as if it were made of two petals joined together. This petal is called the **Standard.** Below and inside this are two narrower petals, one on each side. These are called the **wing** petals. Inside them are two more petals which may be joined together along their lower edges and usually end in a fairly sharply pointed tip. Together they form the **Keel.** Inside the keel you will find the stamens, tightly bunched together, and you will probably find at the tip of the keel a mass of brightly coloured pollen. Careful counting will show you that there are ten stamens. The counting is best done on a young flower, for when the stamens have begun to wither they are difficult to see clearly. You will see that the stalks of the stamens are joined together a short distance from the anthers so that they form a closed tube. Inside this tube is the pistil. The stigma and part of the

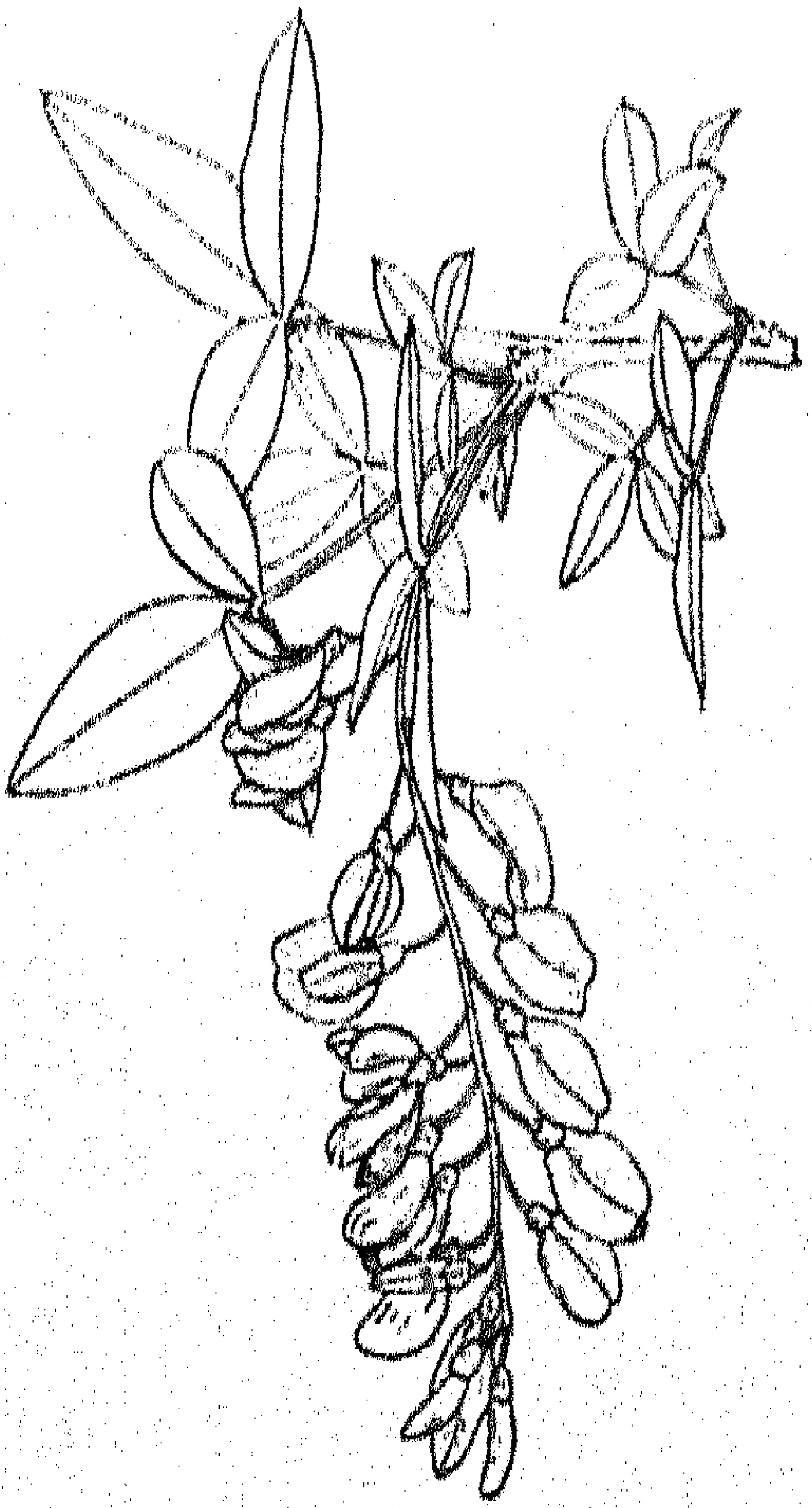

Fig. 9.—A spray of laburnum, × ½.

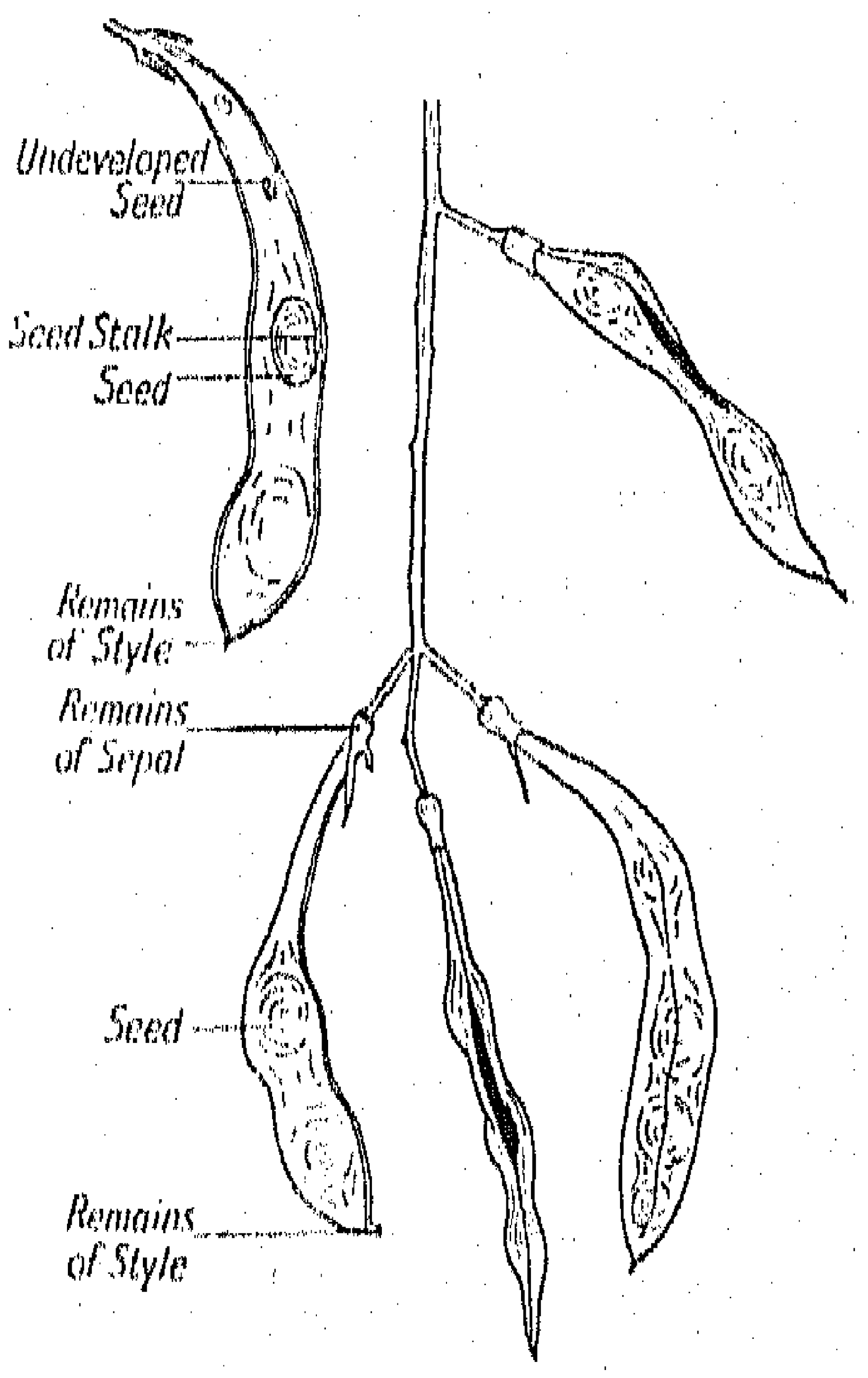

Fig. 10.—Fruit (pods) of laburnum, × ½. *Left:* a single pod opened to display the seeds, × 1.

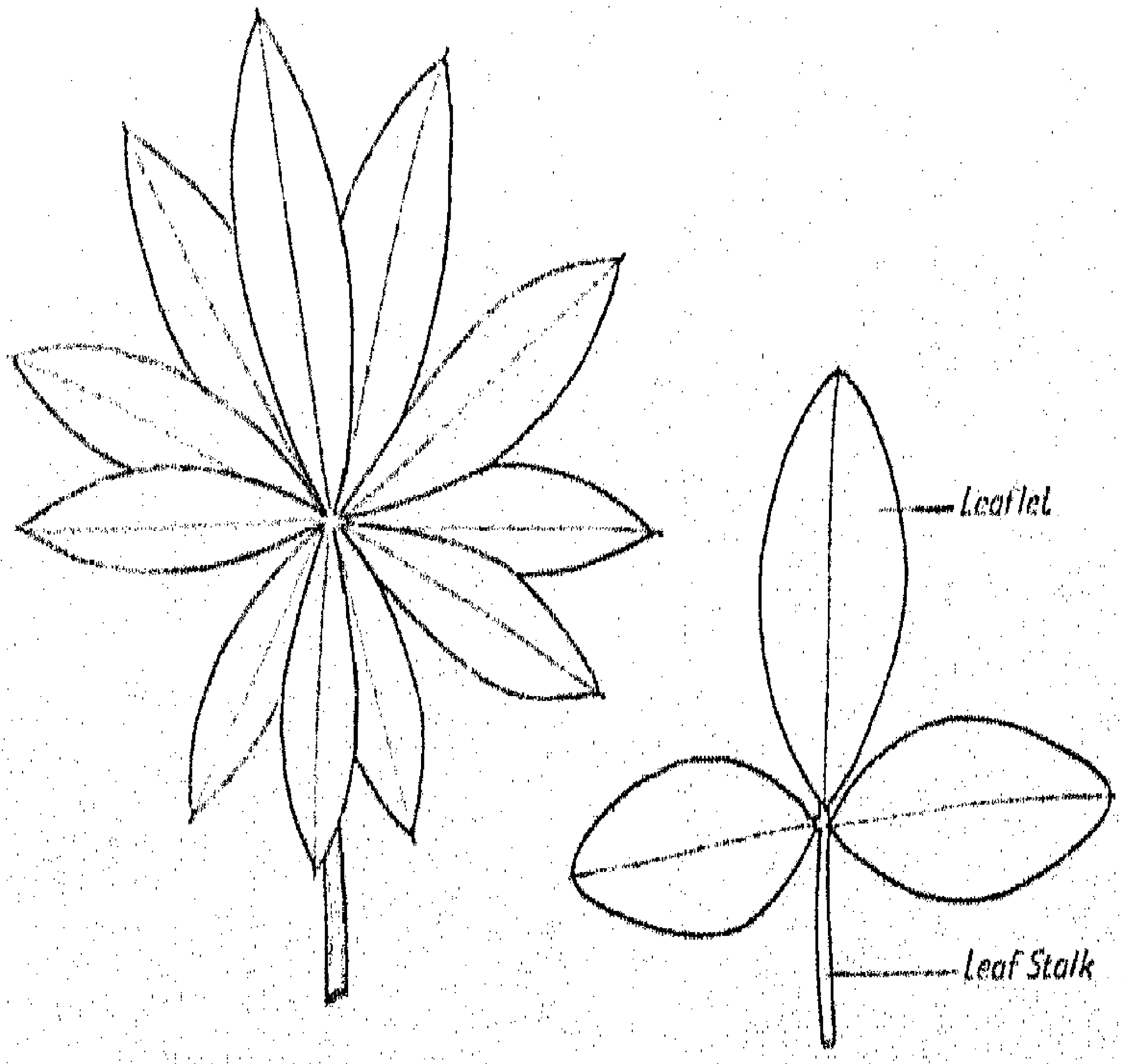

Fig. 11.—*Left:* palmate leaf of lupin. *Right:* pinnate leaf of laburnum (both × ½.)

style may be seen sticking up among the stamens. By splitting the stamen tube with a needle and removing it, you will be able to see the ovary. In flowers whose petals have dropped, the ovary is bigger and easier to see. In time it develops into the ripe fruit.

You will be familiar with the ripe fruits of the Pea Flower family. We call them pods, and examples are the pods of peas and beans. All pods are similar in that they are made of two halves (or valves) which open when the fruit is ripe and expose the seeds. These lie in a single row and are attached to the top edge of the pod, each one by a short stalk which is expanded into a broad pad where it is fixed to the seed. The structure of the seed is described on p. 223.

Here is a key to the names of those members of the Pea Flower family commonly grown in gardens and parks. Gorse, Broom, and Needle-whin also grow in the wild state.

A KEY TO THE COMMONLY CULTIVATED LEGUMINOSÆ

1	Trees and shrubs of woody nature	2
	Herbaceous and annual plants	15
2	Climbing	3
	Not climbing	4
3	Flowers bright red: fern-like leaves	LOBSTER CLAW
	Flowers mauve, rarely white; in hanging sprays	WISTARIA
4	Flowers partly or entirely yellow	5
	Flowers not yellow	12
5	Branches thorny or spiny	6
	Branches without thorns or spines	8
6	Leaves large, fern-like	*Cæsalpinia japonica*
	Leaves small or absent	7
7	Leaves absent, plant spiny all over	GORSE
	Leaves on young shoots, spines on older branches	NEEDLE-WHIN
8	Young stems square; leaves small, each with three leaflets	BROOM
	Stems not square, leaves larger than 1 inch	9
9	Leaflets in threes; flowers in hanging sprays	LABURNUM
	Leaflets in more than threes; flowers not in hanging sprays	10
10	Leaves palmate (see Fig. 11); rounded shrub; flower spikes upright	TREE LUPIN
	Leaves pinnate (see Fig. 11)	11
11	Leaflets in fives; rounded shrub; flowers in small clusters	SCORPION SENNA
	Leaflets eleven; flowers in small clusters; bladder-like seed pods	BLADDER SENNA
12	Flowers in upright spikes	13
	Flowers not in upright spikes	14
13	Young stems square; leaves small, in three leaflets; flowers of several colours	BROOM
	Leaves palmate (see Fig. 11); rounded shrub; flowers white or blue	TREE LUPIN
14	Large heart-shaped leaves; flowers rosy purple	JUDAS TREE
	Leaves pinnate (see Fig. 11); flowers in hanging sprays; white, rarely rose	LOCUST OR FALSE ACACIA
15	Plants climbing	16
	Plants not climbing	19
16	Stems round	17
	Stems angular or square	18
17	Climbing by twisting stems; flowers red or white in spikes	RUNNER BEAN
	Climbing by leaf tendrils; flowers greenish white in ones or twos	GARDEN PEA
18	Many flowers, usually more than 6; rose and maroon, rarely white	EVERLASTING PEA
	Flowers larger than in the Everlasting Pea, usually 2 or 3; various colours	SWEET PEA
19	Leaflets in threes; nearly heart-shaped	DWARF BEAN
	Leaflets not nearly heart-shaped	20
20	Leaves palmate (see Fig. 11), large; flowers in upright spikes	GARDEN LUPIN
	Leaves not palmate	21
21	Leaflets large, 2 to 5; flowers white with black blotch	BROAD BEAN
	Leaves pinnate (see Fig. 11); flower spikes from leaf axils, blue or white	GOAT'S RUE

Pronunciation:
Cæsalpinia japonica (see-zal-pin-e-ah jap-on-ik-ah)

Grasses

All those plants we call grasses are included in the group of flowering plants, and are a family of the monocots. They have flowers which are small and since they do not possess brightly coloured petals, the average person is not much interested in them. However, grasses form the bulk of the world's food supply, either eaten as they are (the fruit of wheat, oats, rice, maize and others) or after they have been eaten by livestock and converted into meat, milk and eggs.

There are many different grasses in England. One, which is very common indeed, is the ANNUAL MEADOW GRASS (*Poa annua*, po-ah an-new-a, Fig. 12). You are almost certain to find this either as a weed in the garden or growing in any waste ground or by the roadside. It is in flower from February to November, and in January 1947, I found a specimen in flower in the centre of Coventry.

Use the illustration to help you to find a plant: there will probably be several in your garden. Dig it up, wash the soil from its roots, and examine it. You will need your hand lens and a pair of mounted needles.

The roots appear as a mass of fine threads, which we call a fibrous root system to distinguish it from tap root systems such as those of carrots, or parsnips, or dandelions. The plant itself is tufted, which means that several stems arise from the root system. Each stem bears several leaves which arise in order from opposite sides. Examine a leaf closely. You will see that it has a prominent vein running down the centre, with other finer veins running parallel to it. Remember that the possession of parallel-veined leaves is one of the characters of monocots.

The leaf is not fixed to the stem at the point where it leaves it, but it is wrapped round it to form a sheath which runs down the stem, often for an inch or more. Then the leaf base ends suddenly at a thickened ring on the stem called a node. Carefully strip off a leaf (the sheath will tear easily) and examine the junction between the leaf blade and the sheath. You will find that the sheath is continued upwards a little way past its junction with the blade, to form a very thin transparent wall, rather pointed in the middle. This is called the ligule. In the growing plant it is tightly pressed against the stem and is thought to prevent water running down between the leaf

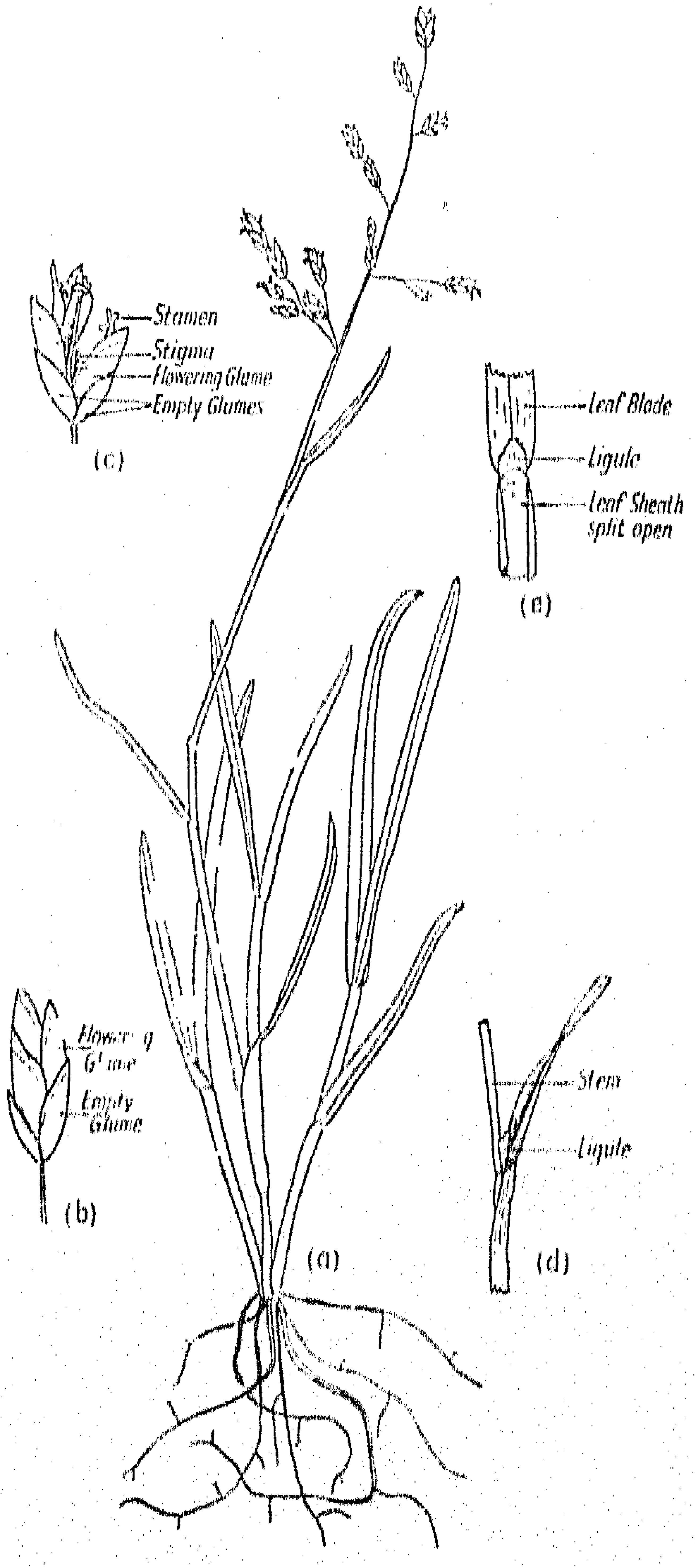

FIG. 12.—(*a*) a plant of Annual Meadow Grass (*Poa annua*), ×1; (*b*) a single spikelet before flowering, ×4; (*c*) a spikelet in flower, ×4; (*d*) portion of stem and leaf to show position of ligule, ×1; (*e*) portion of leaf to show ligule and split sheathing base, ×2.

sheath and the stem, an event which might eventually cause the leaf sheath to rot.

Some of the main stems will end in a cluster of flowers. All the flowers together on one stem form an *inflorescence* (in-flo-res-sence). The inflorescence is made up of smaller units called spikelets, and each spikelet in *Poa annua* consists of from two to six actual flowers. Look at Fig. 12 to help you to understand all this. The flowers in a spikelet are rather tightly pressed together and, unless the flower is in bloom, you will see only the greenish glumes which protect the delicate stamens and the pistil. Spikelets in bloom are yellowish and look quite different from those not in bloom, and are easily recognised. With your hand lens you should have no difficulty in seeing stamens and the tips of stigmas, but not much of the structure and arrangement can be distinguished.

Take a pair of needles and tease out a spikelet that is in bloom. With care you should be able to obtain the pistil. You will see the ovary as a shiny dark green body, almost round. From the top of it arise the two branches of the stigma. These are pearly white and very feathery. Patience and skill are required to obtain an undamaged pistil.

The plants of Annual Meadow Grass go through their life cycle in a few weeks. That means that the seed germinates, grows into a new plant which flowers and ripens its seeds, and then the plant dies down, all in the space of a few weeks.

Other grasses have larger flowers and you should constantly be on the alert to find specimens of these. In some grasses the stamens hang a long way out when the grass is in bloom, and their structure is easily seen with the naked eye. You will see that the anthers are attached by one side to very slender stalks. Because of this the wind can easily blow them about and so shake off the pollen. The pollen is carried by the breeze and some may reach the feathery stigmas. These have a better chance of catching pollen than they would have if they were not much branched.

Four other common grasses you should look for are shown in Figs. 13, 14, and 15.

ITALIAN RYE GRASS (Fig. 13*a*) is often used to make lawns and is also sown in grass mixtures that are intended for making

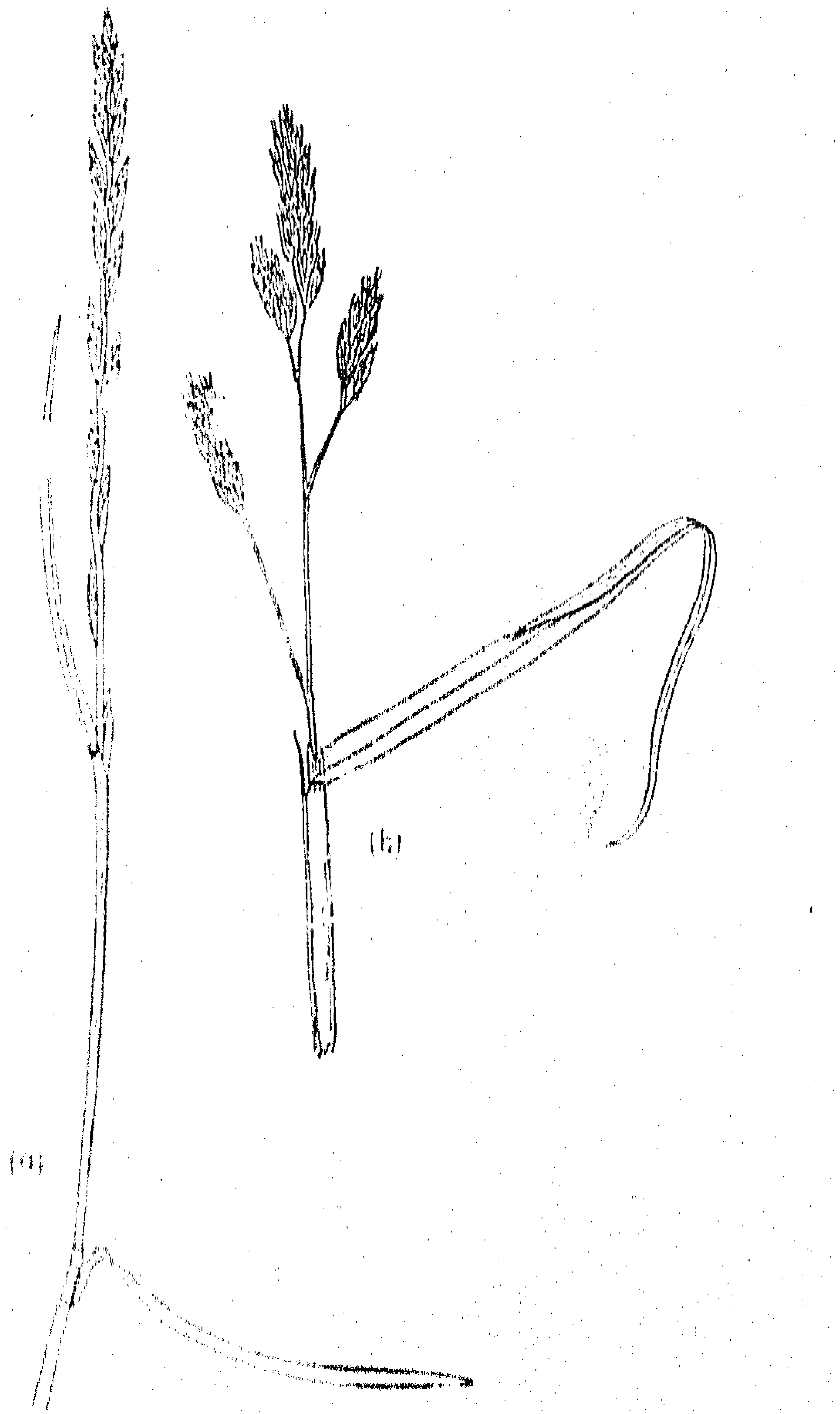

FIG. 13.—(*a*) Italian Rye Grass; (*b*) Cock's Foot Grass (both ×½.)

hay. The spikelets have no stalks and are arranged alternately on opposite sides of the stem. Each spikelet is partly embedded in a groove of the stem and has below it one long glume.

COCK'S FOOT GRASS (Fig. 13*b*)—so called because the inflorescence resembles the foot of a cockerel—is a very coarse grass and forms great tussocks where it grows. The flowering stalks may be upwards of 3 feet high. If you feel the inflorescence, it will be found quite rough to the touch.

AMO-156

WILD BARLEY (Fig. 14). Frequently grows abundantly on waste spaces in towns. It may easily be recognised by the very numerous long awns. Each of these is minutely barbed, and so if one places one of these grass heads, with the stalk pointing upwards, inside one's sleeve when out walking, it will quickly work itself up the sleeve to emerge at the collar.

COUCH GRASS (also called Twitch or Squitch) is one of the worst possible weeds in a garden or field. It sends out long white underground stems in all directions. These come up at intervals

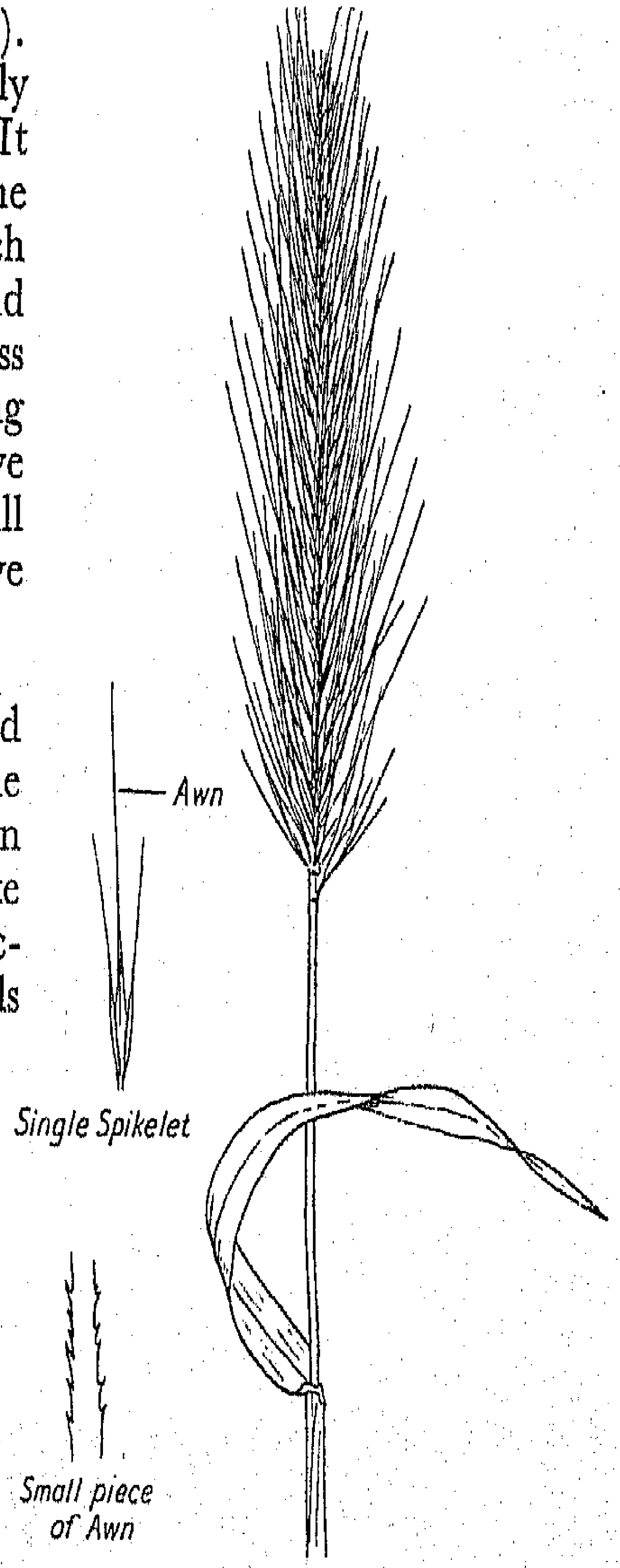

FIG. 14.—Wild Barley, ×1; spikelet, ×1½; piece of awn more highly magnified to show the teeth.

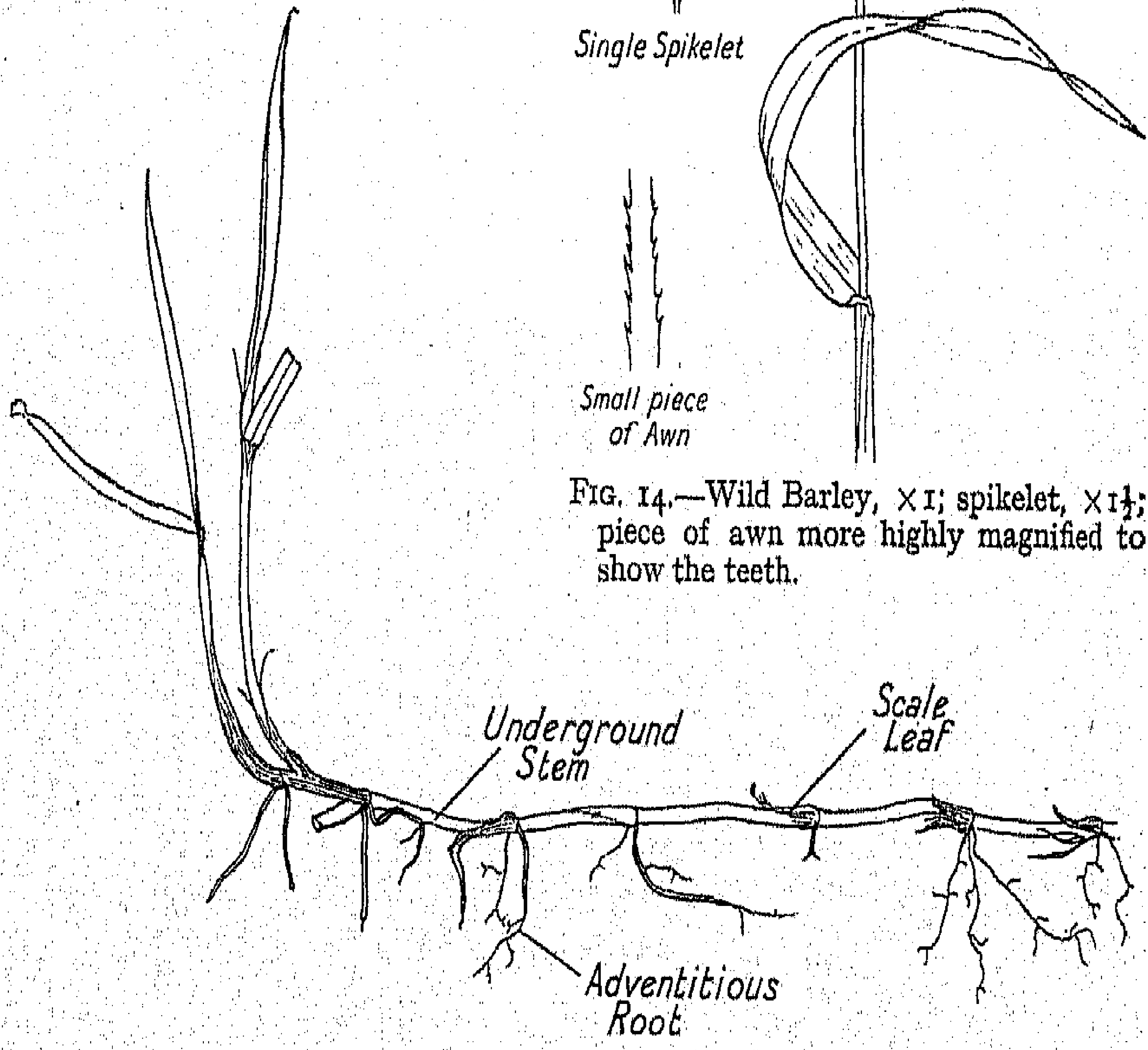

FIG. 15.—Underground stem of Couch Grass, or Twitch, ×1.

to form new grass plants and in a very short time quite large areas of ground will be overrun by them. To eradicate Couch, one has to remove every bit of the underground stems, and as these are brittle and often go deep, this is a difficult job. The grass is most easily recognised by its underground stems (Fig. 15).

Duckweeds

A mass of tiny green plants is often to be found in summer floating on the surface of ponds and canals, and many slow rivers. This is known as duckweed. Collect a small amount and examine it. A single plant of the common species consists of a flat disc, roundish or oval in outline, and often with smaller discs growing out of its sides (Fig. 16*b*). These discs are known as fronds and are really flattened stems, not leaves. We know this because occasionally they bear flowers, and leaves never bear flowers. Hanging down into the water from the centre of the underside of each frond will be a small whitish root. The frond and the root together form a complete plant. Very rarely, in autumn, you *may* find the duckweed in flower, when it will have one or two stamens and a tiny pistil.

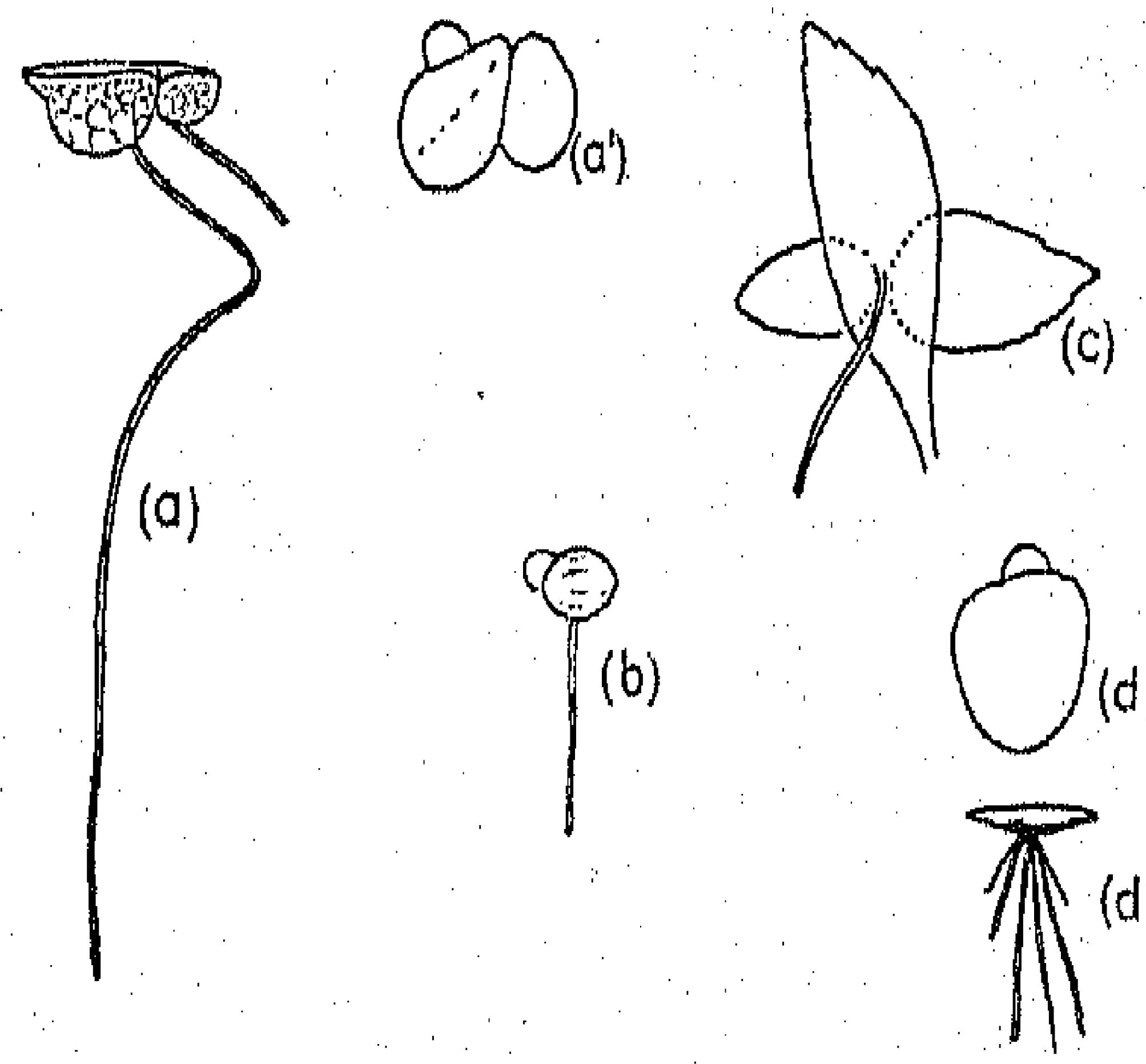

FIG. 16.—Duckweeds. (*a*) Gibbous Duckweed from the side; (*a'*) the same from above; (*b*) Lesser Duckweed, seen obliquely from above; (*c*) Ivy-Leaved Duckweed, from below; (*d*) and (*d'*) Greater Duckweed, from above and from the side. (All ×1½.)

Leave a few duckweed plants to float on the surface of water in a jam-pot. Place the jam-pot where plenty of light falls upon it (but not direct sunlight). If you look at the duckweed after a few weeks you will realise why it is that in summer the whole surface of some ponds may become covered with this plant.

Altogether there are five species of duckweed in Britain. The commonest species is the Lesser Duckweed. The Gibbous Duckweed (Fig. 16*a*) is very much swollen underneath. Although found all over Britain, it is much less common than the Lesser Duckweed, as is also the Ivy-Leaved Duckweed. This latter plant has very irregular outlines to its fronds, which are drawn out at one end into a short stalk (Fig. 16 *c*). The Greater Duckweed has bigger fronds than the other species and moreover has several roots on each frond. It is not common, but occurs here and there in most districts. The Rootless Duckweed, with very small fronds and no roots as its name implies, grows only in the south-eastern counties of England.

All these duckweeds can be kept in jam-pots full of water, but the Greater Duckweed and the Ivy-Leaved Duckweed do not like being exposed to very bright sunlight. I keep them out of doors under an apple tree.

Here is a key that will enable you to find the names of the various duckweeds as you collect them. In one year you ought to find all species, with the possible exception of the Rootless Duckweed.

KEY TO THE SPECIES OF DUCKWEED (Genus *Lemna*)

1 { Frond irregular in outline, nearly ½ inch along its longest axis; continued into a stalk in at least one place — IVY-LEAVED DUCKWEED
Frond rounded in outline — 2

2 { No roots; fronds very small, about 1/25 inch — ROOTLESS DUCKWEED
One or more roots present — 3

3 { Usually more than one root to each frond; fronds at least ¼ inch across, usually more; fronds often purplish underneath — GREATER DUCKWEED
One root to each frond; fronds usually less than ¼ inch across — 4

4 { Underside of frond flattish — LESSER DUCKWEED
Underside of frond very strongly arched, inflated in appearance; the swollen part containing small air chambers — GIBBOUS DUCKWEED

The scientific names of the plants mentioned in this key are:

IVY-LEAVED DUCKWEED	*Lemna trisulca*	(lem-na tri-sul-ka)
ROOTLESS DUCKWEED	*Lemna arrhiza*	(lem-na ar-ri-za)
GREATER DUCKWEED	*Lemna polyrrhiza*	(lem-na pol-o-ri-za)
LESSER DUCKWEED	*Lemna minor*	(lem-na my-nor)
GIBBOUS DUCKWEED	*Lemna gibbosa*	(lem-na gib-bohsa)

Collecting Plants

It is easy to make a collection of plants, and if collections of the common or characteristic plants are made from different types of places (e.g., the seashore, chalk country, and different types of woods), they will help you to realise that a particular plant will not grow everywhere. You should never take away a rare plant merely to add it to a collection. Perhaps I ought also to point out here that as a rule it is useless to dig up a rare plant and take it home with the intention of growing it in the garden, because usually such plants die soon after removal from their natural homes. A garden is a most unnatural place for the majority of wild plants.

To preserve a plant, all that is necessary is to dry it thoroughly. This is done most simply by placing the plant between several thicknesses of newspaper and putting it flat upon a table or on the floor. Then place a board over it and add a number of books on top to provide sufficient weight to keep the newspaper pressed well against the plant. After some days (the actual time will vary with the weather) the plant will be found to be quite dry. It is then removed and fastened to a sheet of plain drawing paper, or thick typewriting paper, with transparent sticky paper tape cut into strips about 1 inch long and ¼ inch wide.

Each specimen should be labelled with its place of origin and the time of the year it was obtained. Notes and sketches of interesting things about it (e.g., any particular beetles or caterpillars found feeding on it, whether it was growing in a special place such as on a pathway, wall, or the site of a fire, and details of its underground parts) can be added to the sheet at the bottom, or to another sheet glued on to the edge.

The specimens are best kept each in a separate fold of newspaper. Tall plants, such as many grasses, will have to be bent into a zigzag shape before being pressed. Plants that have become very limp through losing too much water do not press well. Consequently specimens should be placed in a more or less airtight tin as soon as they are gathered. In this way they will keep fresh for three or four days.

CHAPTER FOUR

Ferns, Horsetails, and Mosses

Ferns

PROBABLY the fern that is the most frequently cultivated in gardens, especially in the midland and eastern counties of England, is the **Male Fern**, *Dryopteris filix-mas* (dri-op-te-ris fil-iks mas).

The stem of the plant is almost entirely underground, and it grows horizontally, bearing a number of black wire-like roots. It is several inches thick and is covered with a mass of brownish black material which is largely the remains of previous years' leaves.

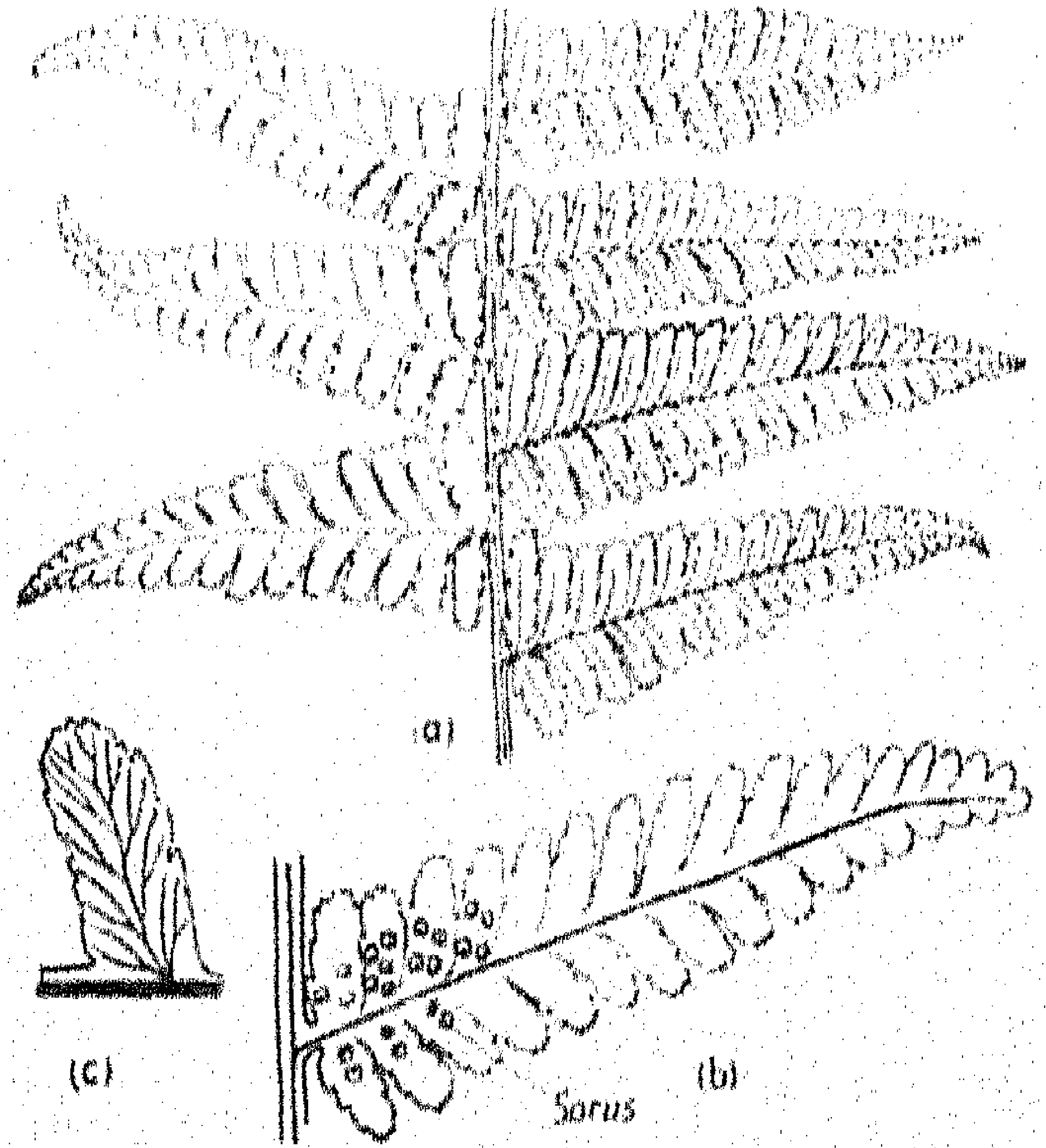

FIG. 17.—Male Fern. (*a*) portion of frond from above; (*b*) a single fertile leaflet from below; (*c*) a segment of a leaf, enlarged to show the mode of branching of the veins. [(*a*) ×½, (*b*) ×1, (*c*) ×2.]

The leaves are given off in a tuft from the youngest end of the stem, where also there may be a number of prominent leaf buds, thickly clothed in soft brown scales.

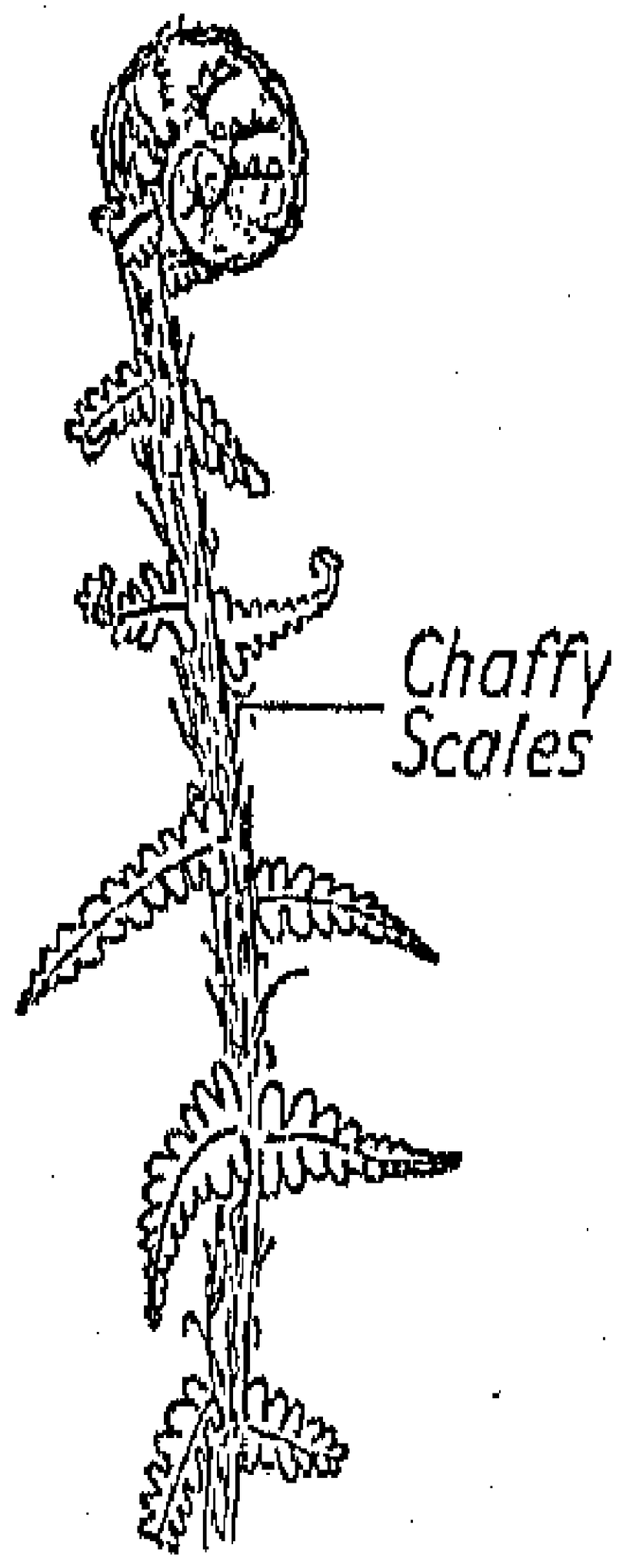

FIG. 18. — A young leaf of the Male Fern, opening (×½).

The leaves of the Male Fern are large. Each leaf blade is broken up into a number of divisions on each side of the thick mid-rib, and each division is again broken up into smaller segments. A leaf such as this, which has the original leaf blade divided into smaller segments, is called a compound leaf. Fig. 17 will make the arrangement clear.

If you look at one of the smallest divisions of the leaf with a hand lens, you will find that it is provided with veins and that each vein branches into two parts as shown in Fig. 17 (*c*). This mode of branching is very characteristic of ferns.

On the under surfaces of most of the leaves you will find prominent swellings which are roughly heart-shaped. In the early part of summer these *sori* are green; but later they become rusty brown, and the heart-shaped cover shrivels to expose a mass of tiny stalks, each with a rather glossy swelling at its tip. These structures are too small to be studied satisfactorily with a hand lens, and it will be sufficient to say that they are the spore cases (Fig. 19). The spore cases are full of spores, tiny little bodies which are liberated in autumn and then grow into a new type of fern plant *quite unlike the parent plant* (see p. 41). If you will refer to p. 224 you will discover that seeds contain young plants tightly enclosed inside them.

Spores do not: they have a much simpler structure than seeds. Again, before seeds can be produced, an ovule has to be fertilised by a male element from a pollen grain, whereas spores are made without any process of fertilisation. However, spores are capable, as are seeds, of growing into new plants. In Fig. 19 are drawings of a fern's spore cases, made with the help of a microscope, to show you what they are like. It is just possible, with a good hand lens, to distinguish the structure.

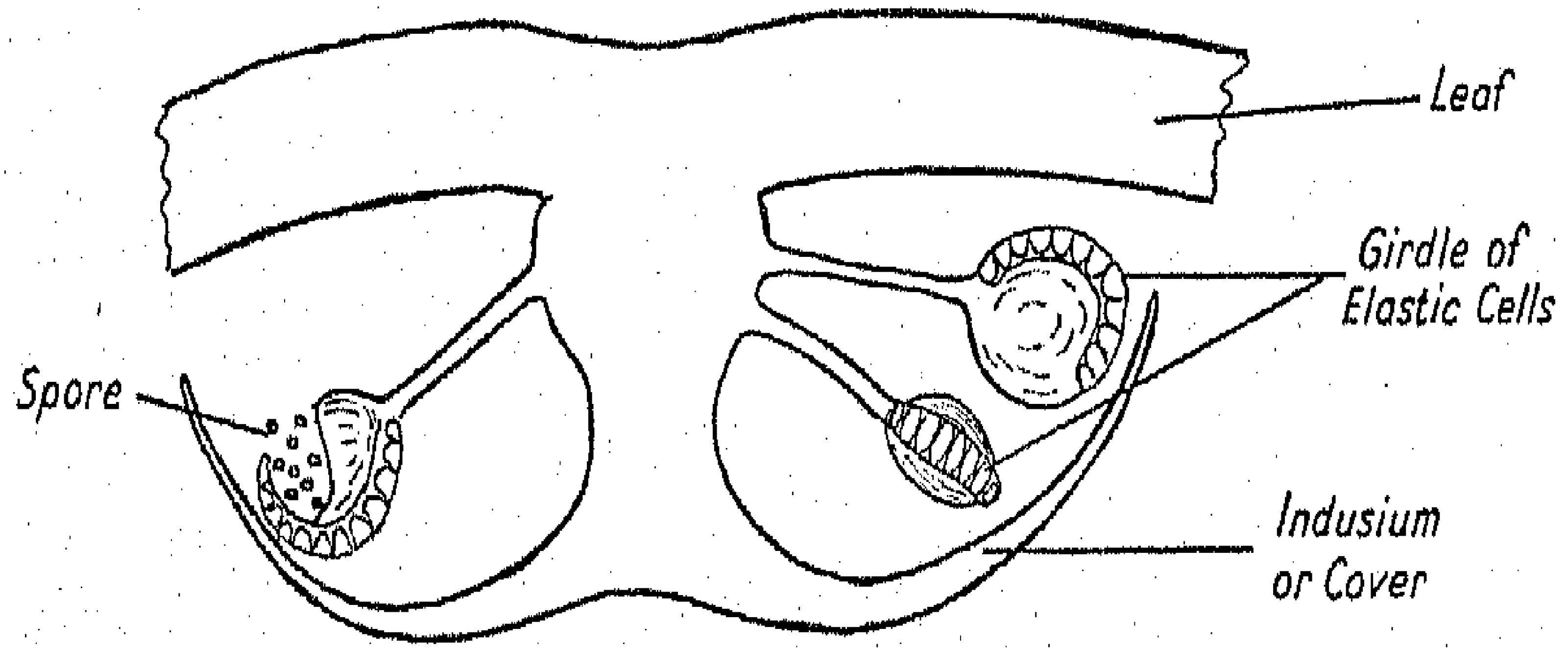

FIG. 19.—Diagrammatic section through a sorus borne on the undersurface of the leaf of a Male Fern, to show the origin of the spore cases and their relationship to the indusium.

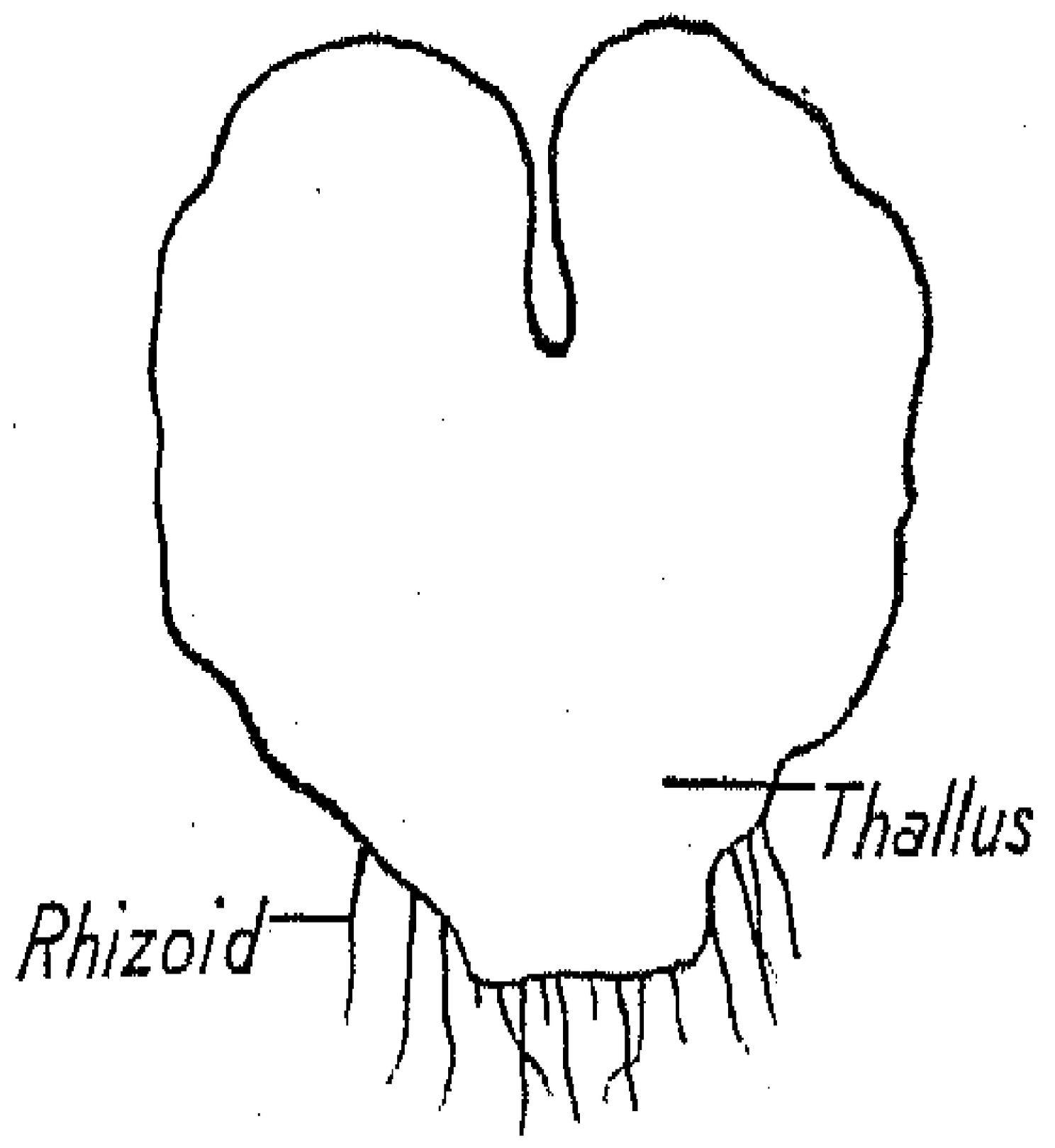

FIG. 20.—A fern prothallus, seen from above, × 6.

When a spore of a fern falls to the ground in a suitable place, it germinates and grows into a flat sheet of green tissue which is rather less in size than the top of a lead pencil. This structure is called a *prothallus*. It is shaped as shown in Fig. 20, and is rooted to the soil by a number of hair-like structures growing from underneath it. In time, from this prothallus a new fern plant grows (Fig. 21).

Prothalli are not very easy to find. They are quite small and delicate, so that in dry weather they tend to dry up rapidly and die. To find them, you must look in places that are always more or less damp. In some towns you will find gardens built up behind stone walls several feet above the road. Often the wall separating the soil from the footpath shows damp patches where water drains through. I have frequently found fern prothalli growing between the stones in such places. Usually I first notice them because there are tiny ferns growing on some of them. Fig. 21 is a drawing of one such prothallus and fern taken from a wall in Coventry during early October. In the west of England, which is wetter than most other parts, fern prothalli are not so difficult to discover, and ferns are much more abundant.

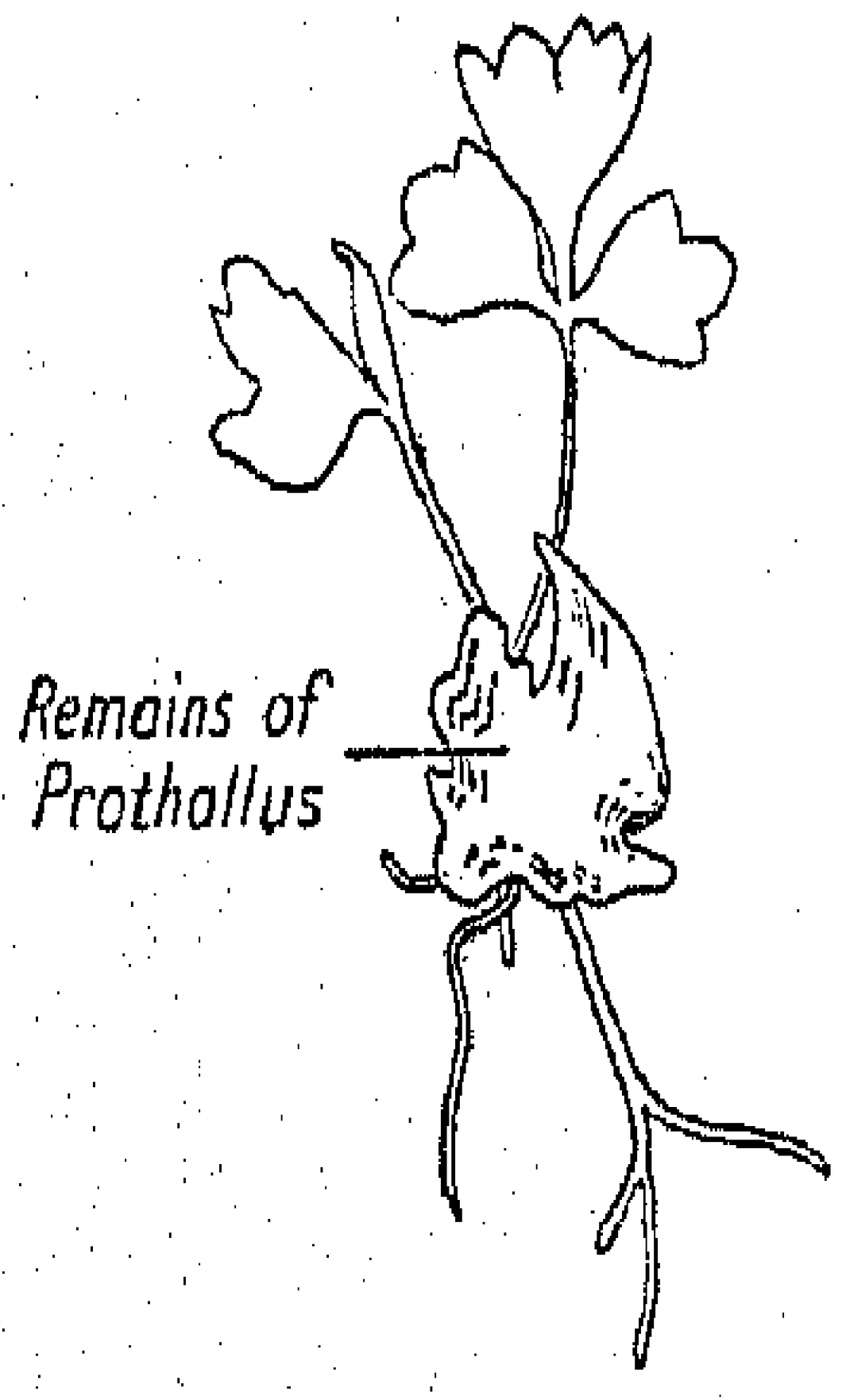

FIG. 21.—A young Male Fern, still attached to its prothallus, ×1½.

If you can obtain a fern prothallus, with a young fern growing from it, you should be able to see that the young fern arises from underneath the prothallus and then bends forward through the notch in the edge of the prothallus. You will see at once that the young fern leaves are simpler and of a rather different shape from those of the more mature fern. As the young fern plant grows bigger, the prothallus dies away and the roots of the fern become established in the soil.

Bracken is perhaps the best known of all our ferns, for, in waste places, on commons and heaths, and in many woods throughout Britain, it grows in great expanses. The stem

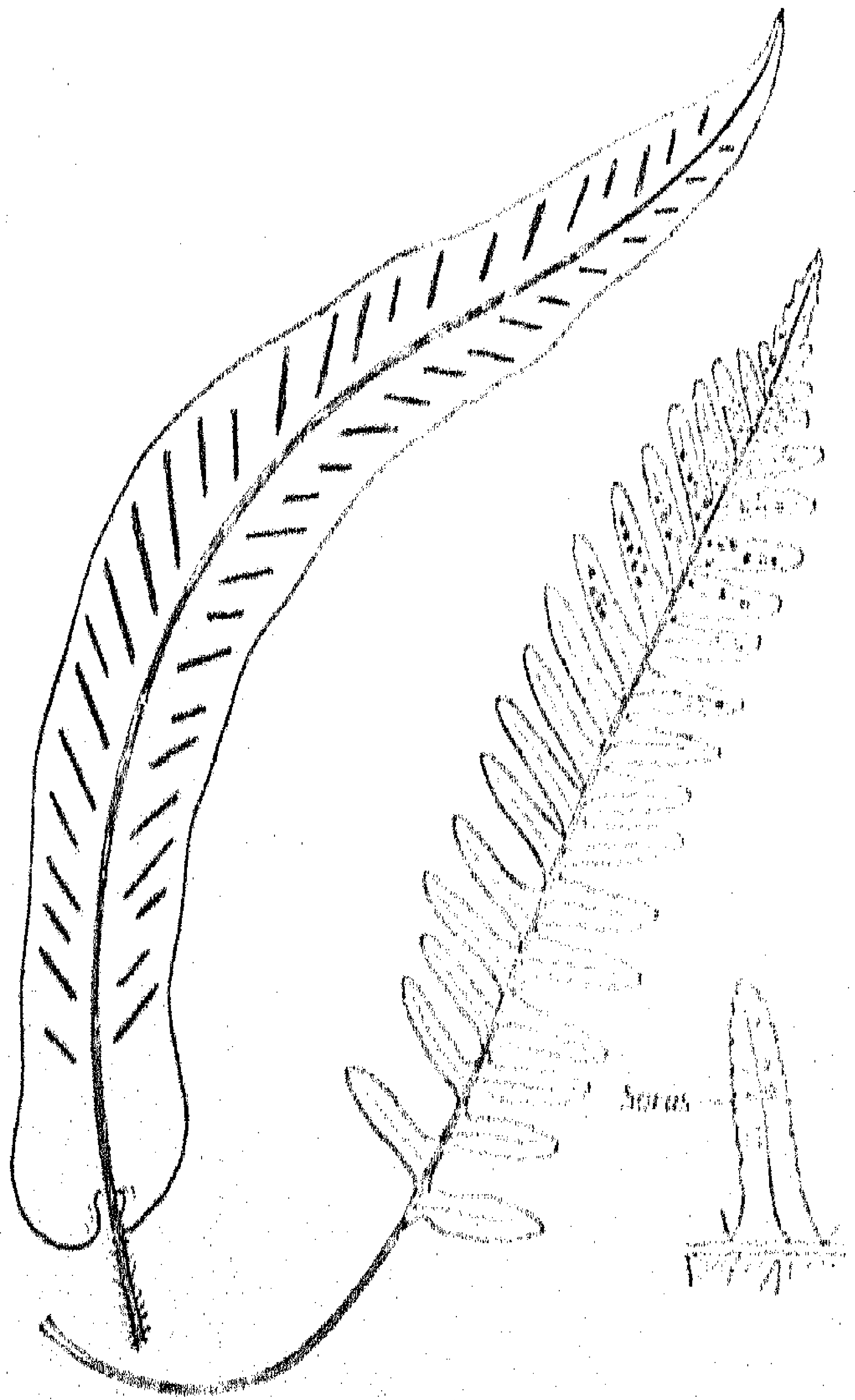

FIG. 22.—*Left:* a frond of Hart's Tongue Fern, × ¼; *centre:* a frond of Common Polypody, × ¼; *right:* a segment of the leaf of the Common Polypody showing the sori, which here are not covered by an indusium, × 1. All seen from below.

grows underground and branches repeatedly, so in this way bracken will gradually extend its range, once it has obtained a foothold. At intervals the stem gives off leaves which are even more divided up than those of the Male Fern. The smallest segments of the leaves are different from those of the Male Fern in that the veins join together at the edges of the leaves to form a continuous vein round the margin. The spore cases also are found round the margins underneath the leaves, whose edges are inrolled to form a protection for them.

Bracken is very sensitive to frost, which at once kills both the young shoots in spring and the mature plants in autumn. In autumn the leaves of the old plants turn a rich brown colour and may remain standing all winter. In some areas bracken is a great nuisance to farmers, for it may invade fields by means of its underground stems and render useless what was once good pasture. When it has become established bracken is very difficult to control. It grows abundantly on many of the hill sides in Wales, where it is cut and harvested for use as bedding material for farm animals.

The Common Polypody, *Polypodium vulgare* (pol-e-pod-e-um vul-gar-ay) and the **Hart's Tongue Fern** are two kinds you will find growing abundantly in the west of England and in Wales. The Hart's Tongue Fern is also grown in gardens in other parts. The Common Polypody often grows on walls. The leaf is not much divided and the spore cases, which grow on the underside of the leaf as rusty brown patches, have no cover (Fig. 22 *right*). The Hart's Tongue Fern has leaves which are not divided at all. They are long and broad and the spore cases form rows running across the under surface of the leaves like rusty bars (Fig. 22 *left*).

Many ferns are cultivated in pots indoors. The **Maidenhair Fern** is one, which you can recognise because the spore cases are produced in small cup-like depressions at the edges of the leaves. There is another fern, *Asplenium bulbiferum* (as-pleen-e-um bulb-if-er-um), which has young ferns growing directly from its leaves. If these are removed and planted in soil, they will continue to grow.

If you are in doubt whether a plant is a fern or not, and you cannot find the spore cases, look at the side veins in the leaves. If these fork into two more or less equal branches, the plant is almost certainly a fern.

Horsetails

In Fig. 23 I have drawn specimens of a curious plant known as the FIELD HORSETAIL, *Equisetum arvense* (ek-we-see-tum ar-ven-say). These plants do not grow everywhere, but, where they do grow they may become a serious nuisance to gardeners. They tend to prefer a rather dry situation such as a railway bank or waste land.

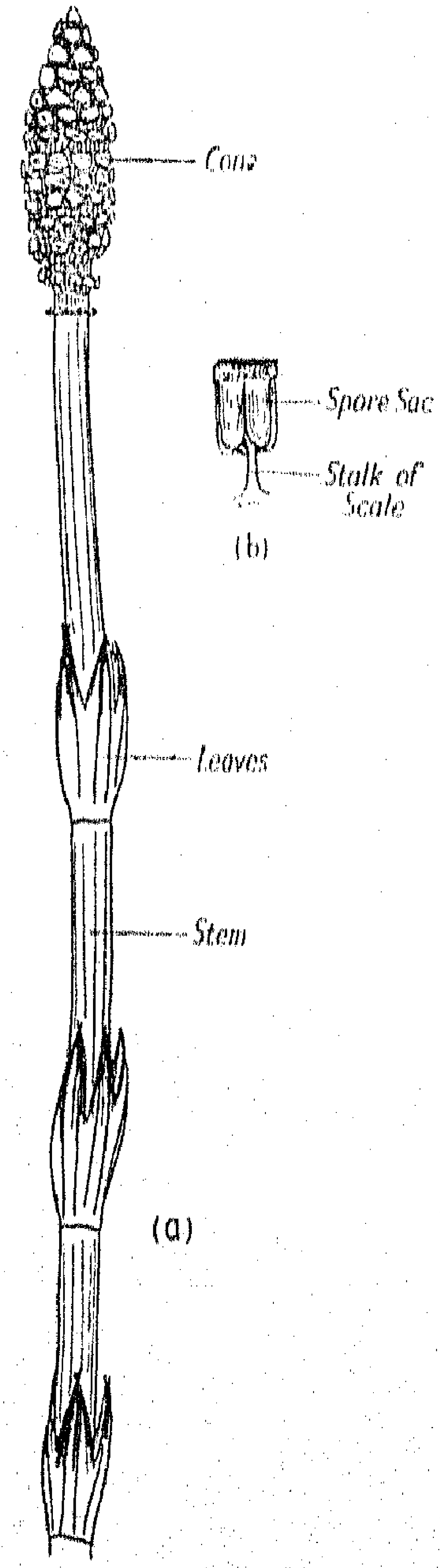

FIG. 23. — (*a*) fertile shoot of Field Horsetail, bearing a cone at its apex, ×1; (*b*) a single scale from the cone, ×4.

The first parts of the plant to appear above ground are the cones (Fig. 23). These are borne at the end of stout stems which are pale yellowish-brown in colour. Each cone consists of a central axis to which are attached very many scales which are roughly six sided. Each scale is fixed to the central axis by a stout stalk running from the centre of its under surface. On this under surface are also several chambers containing spores (Fig. 23*b*). Around the stem at the bottom of the cone is a ring of tissue called the *annulus* (an-new-lus).

When the cone first appears, the scales are tightly packed together. Soon, however, they become separated because the central axis grows longer, and then the spore chambers are visible. The spore chambers now burst open (early May) and the yellow spores are set free and blown away. They germinate to give rise to structures not unlike the prothalli of ferns (see p. 41), and from them new horsetails may arise.

The stalk bearing the cone is peculiar in that it appears to be made up of many segments (Fig. 23). At each node is a circlet of pointed leaves joined together by their bases. These leaves tightly clasp the stem and their tips are dark brown.

After the cones have liberated their spores, they die away, together with the stems that supported them. However, new stems now come above ground. These are the green stems that make food for the plant and they have a characteristically regular shape. At each node on the main branch (i.e., where the leaves occur) a whorl of smaller side branches is given out. These have the same structure as the main branch, being made up of numerous segments, each with a circlet of leaves at its base, and in their turn they give off whorls of branches at each node (Fig. 24).

The stems are coarse to the touch and have a number of

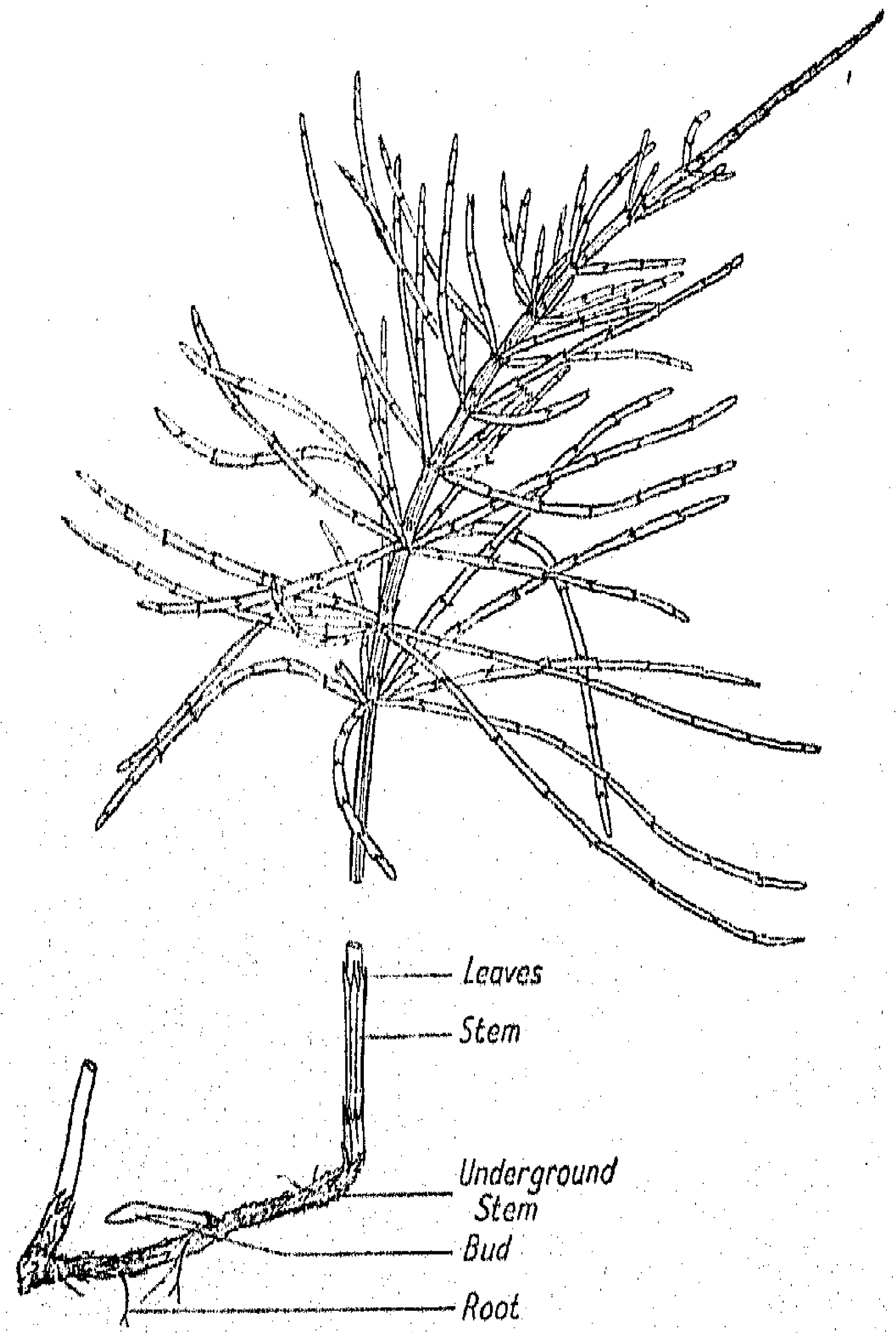

FIG. 24.—Vegetative branch of the Field Horsetail, ×½.

shallow grooves running along them. When pulled, the stems come to pieces very easily, breaking off at the nodes, and it is a favourite pastime of country children to take a horsetail plant to pieces bit by bit in this manner.

The various overground stems are all connected to other dark coloured stems growing below the surface of the ground. These underground stems often go down to a depth of 3 feet and give off rootlets at intervals. This habit makes the Field Horsetail a difficult pest to eradicate once it becomes established in a garden.

There are other Horsetails in Britain in which the cones are borne upon the ends of the branches of the main plant. The Giant Horsetail which is occasionally to be found growing in rather damp situations, is a magnificent plant 5 to 6 feet high.

At the present time the Horsetails are an unimportant group of plants, but they have not always been so. In remote geological times they were one of the dominant groups of plants, possessing forms that were similar to tall trees. Horsetails were abundantly represented in the floras of the vast Carboniferous swamps in which, some two hundred and fifty million years ago, our coal was being formed.

Mosses

There are many different kinds of mosses and all the common ones are rather small. However, as their fruiting bodies are often most conspicuous, an attempt must be made to tell you something of these plants.

Mosses grow on walls, roofs, in the blocked-up gutters of houses, on damp pathways, in lawns, and upon waste ground, as well as on the floor of woods. The moss I have chosen to describe is called *Funaria hygrometrica* (few-nare-e-a hy-gro-met-rik-a). It grows upon waste ground, particularly in places where there has been a fire. The specimen drawn in Fig. 25(*a*) came from an old pile of cinders in the garden.

The *Funaria* plants grow clustered together forming a close carpet about ½ inch deep. Covering an area of a square inch there may be as many as 1,000 plants, so tightly are they massed. Each plant consists of a central stalk which is clothed in a number of delicate green leaves. When the plant is dry, the separate leaves are difficult to distinguish even with a hand lens, but, if the plants are soaked in water, the leaves become much more distinct. The lower end of each stem is loosely covered by withered brown leaves and is continued under the soil as a dark brown stalk which gives off a number of root-like hairs. These structures, called *rhizoids* (ry-zoids), perform the same functions as the roots of flowering plants, but are much simpler in construction. The main stem may branch once or twice, low down, so it may appear as if two or three *Funaria* plants were arising from the same underground part.

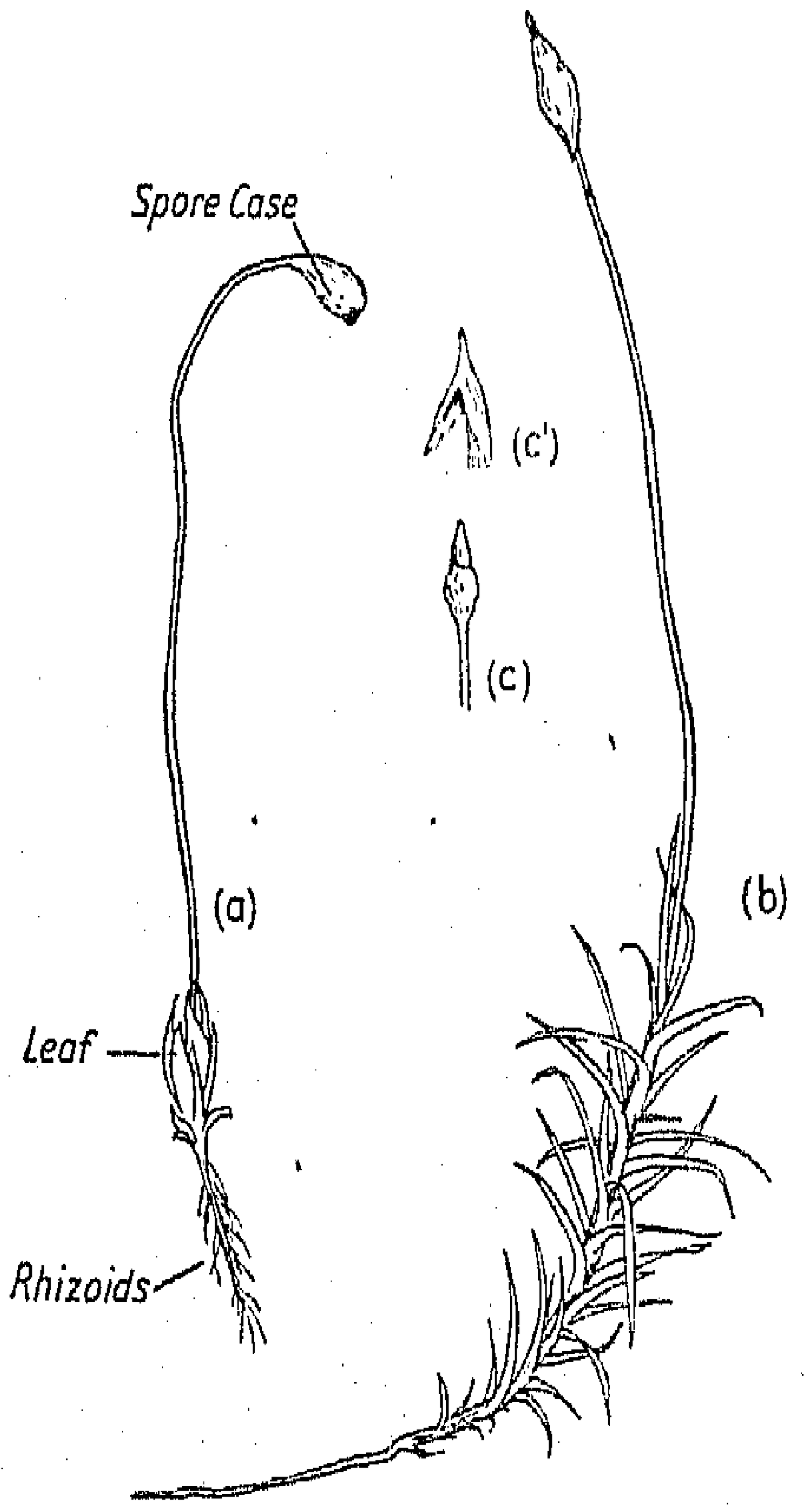

Fig. 25.—(*a*) *Funaria hygrometrica*, ×3; (*b*) *Polytrichum* (*species?*), ×2; (*c*) spore case of *Polytrichum*, and (*c'*) cap (calyptra) of same.

At most times of the year, you will find that a number of the *Funaria* plants in a particular patch are carrying fruiting bodies. These are pear-shaped chambers borne on the ends of slender stalks an inch or more in length. The pear-shaped bodies are the spore cases, all full of very tiny bodies called spores—each of which is capable, under suitable conditions, of growing into a new *Funaria* plant.

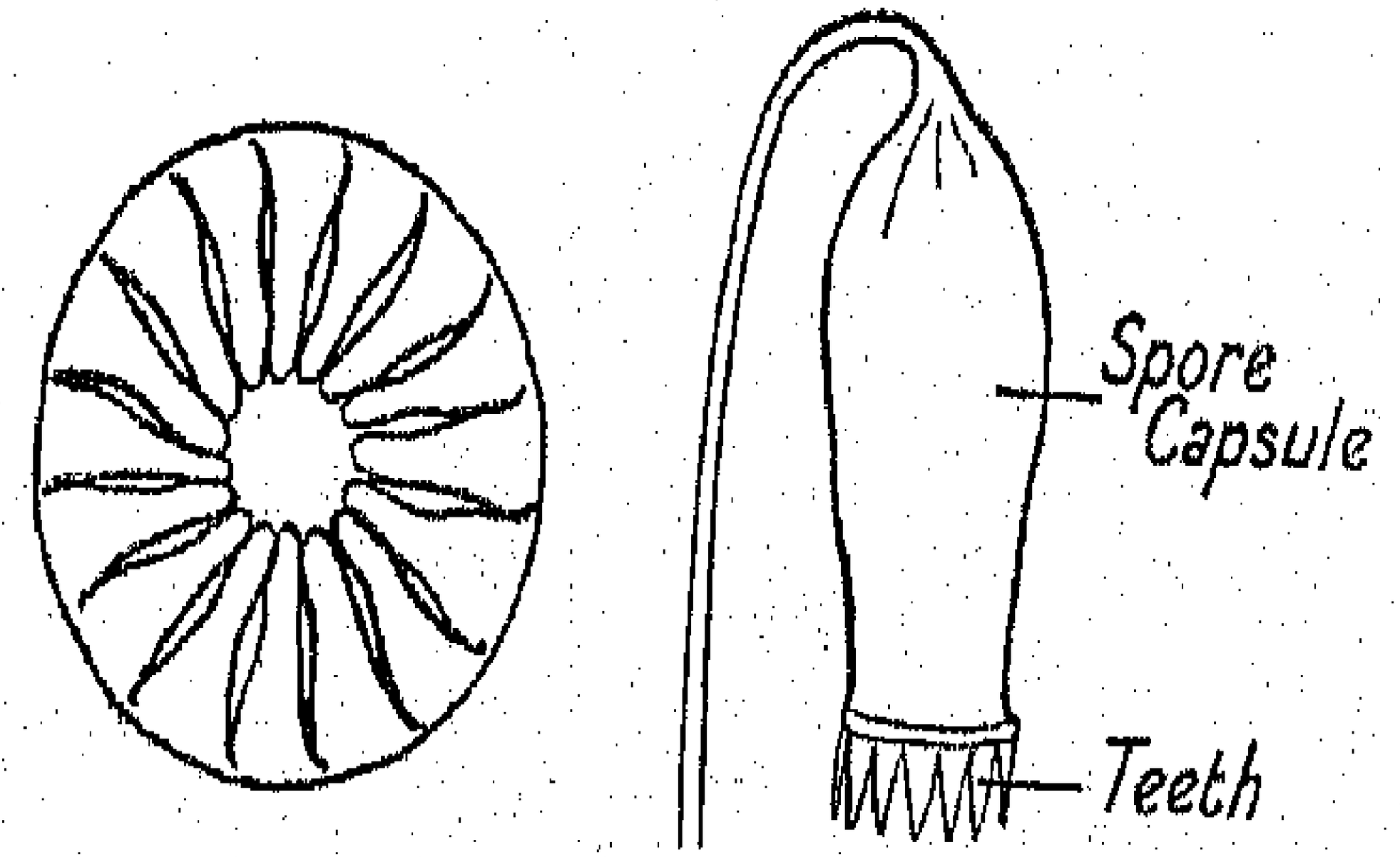

Fig. 26.—Drawing to show the arrangement of the teeth closing the mouth of the spore case of *Funaria*. Much enlarged.

The spore cases are green when they first develop, but gradually they turn golden, and then a deep brown. The free end of each case is at first closed by a lid shaped like half a tennis ball. As the spore case ripens, this lid falls off, but still the mouth of the case is closed by a number of teeth arranged as shown in Fig. 26. When the weather is dry, these teeth open outwards to allow the spores inside the spore case to be shaken out and blown away by the wind.

A moss commonly found growing on walls in towns is *Tortula muralis* (tor-tu-la mewr-ay-lis). The actual plants are barely ⅛ inch high and the stalks of the spore cases no more than ½ inch long. The moss grows in tight cushions pressed close to the stonework and from these cushions numerous spore cases grow out. Each spore case sticks straight upwards from the end of the stalk that bears it (Fig. 27*a*). The leaves of this moss are quite small and usually dried up, but, if the plants are first soaked in water and then examined through a hand lens, it will be seen that each leaf is continued at the tip into a hair-like point (Fig. 27*b*), also that the leaves are curled inwards along their edges.

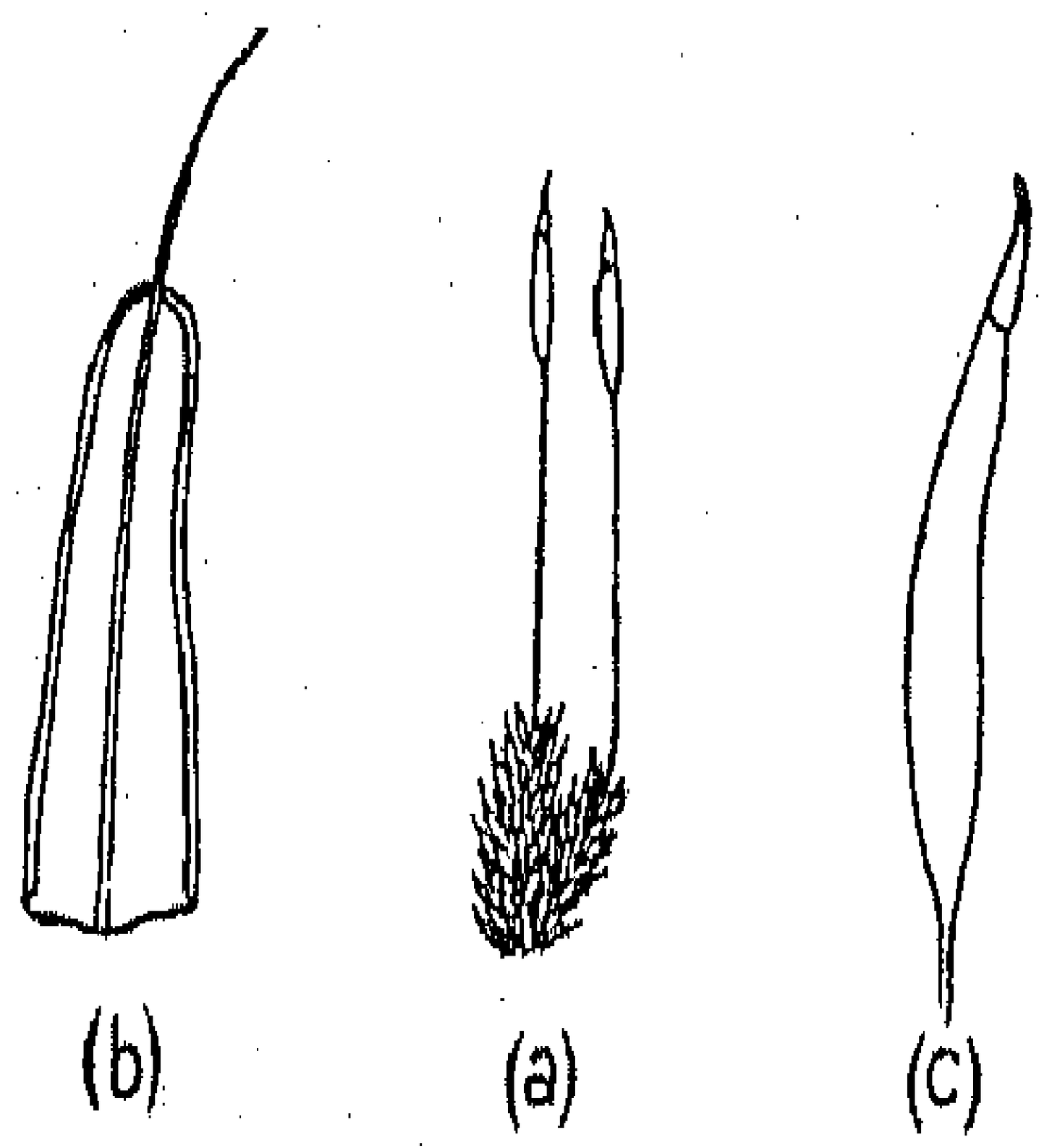

FIG. 27.—(*a*) *Tortula muralis*, ×2; (*b*) single leaf, and (*c*) spore case, of same, both ×10.

A moss often to be found on heaths or the floors of woods is shown in Fig. 25(*b*). This is a species of the genus *Polytrichum* (pol-e-tri-kum). It is much larger than the other mosses mentioned. The spore cases are usually covered with a cap of silky material somewhat like a dunce's cap. If you remove this, you will find the spore case underneath.

Mosses may be dried and pressed in a similar way to other plants (see p. 37). When dry, they can easily be fixed into an exercise book with strips of gummed paper and can form an attractive collection.

CHAPTER FIVE

Moulds, Toadstools, and other Fungi

Moulds

YOU will frequently find tiny plants called moulds growing on stale bread, old cheese, damp leather, rotten fruit, and suchlike substances. Moulds are members of the FUNGUS group. We will study particularly the BLACK MOULD, *Mucor* (mew-kor) because this is rather easy to grow at home.

Mucor may easily be grown upon boiled potato. Boil a fairly large potato in its skin, after washing away any dirt. Then mash the potato and squeeze it into a cake that will fit easily inside the mouth of a two-pound jam-pot. Place the cake of potato on an old saucer and sprinkle some dust on it or simply leave it exposed to the air for half a day. Then cover it with the jam-pot and place it in a warm cupboard.

After a few days the potato should be covered with a pale silky growth. If you examine this under a hand lens, you will see that it is made up of innumerable thin glistening threads, to all appearances inextricably entangled. The threads are the body of the *Mucor* plant. Each thread is called a *hypha* (hy-fa: hy-phee pl.), and all the threads together are called the *mycelium* (my-see-le-um). Many of the hyphæ will be buried in the potato on which they are feeding. They are very delicate and are likely to shrivel if left exposed to dry air for many minutes.

For a few days the mycelium is all that there is to be seen of the *Mucor*. A little later, however, the mycelium begins to produce structures connected with reproduction. These are the spore cases, and they are easily visible to the naked eye as little black swellings at the ends of hyphæ which stick up into the air, so that each spore case on its stalk looks like a tiny pin with a jet black head.

Inside each spore case are the many tiny oval spores, but they are far too small to be seen even with a hand lens. The spores are special units that the plant breaks off from itself for the purpose of reproduction. They are blown away by the wind and grow into new *Mucor* plants if they fall on suitable material. As they are produced in immense numbers, they are present in almost any sample of dust.

If you leave the piece of potato, you are almost certain to obtain other moulds on it, but usually they take rather longer than the *Mucor* to grow. That remarkable drug PENICILLIN, which is of such value in the treatment of many of the diseases caused by those small germs called bacteria, is obtained from a mould called *Penicillium notatum* (pen-e-sil-le-um note-ay-tum). This species is rather rare, but another species, *Penicillium glaucum* (p. glaw-kum), is probably the commonest mould in the world. It is found on cheese, damp leather, fruit and bread, and is almost certain to grow on the potato. Here the spores are borne in long chains, but, as several chains start from near one another at the tip of a hypha, the appearance under the microscope is rather like a tuft. The spores are green.

Another fungus, which has green spores, will appear on a slice of bread kept for about ten days in an empty cocoa tin with the lid on. This is called *Eurotium* (yewr-oh-te-um). The spores here also are freely exposed to the air, and can be seen with a hand lens (Fig. 28).

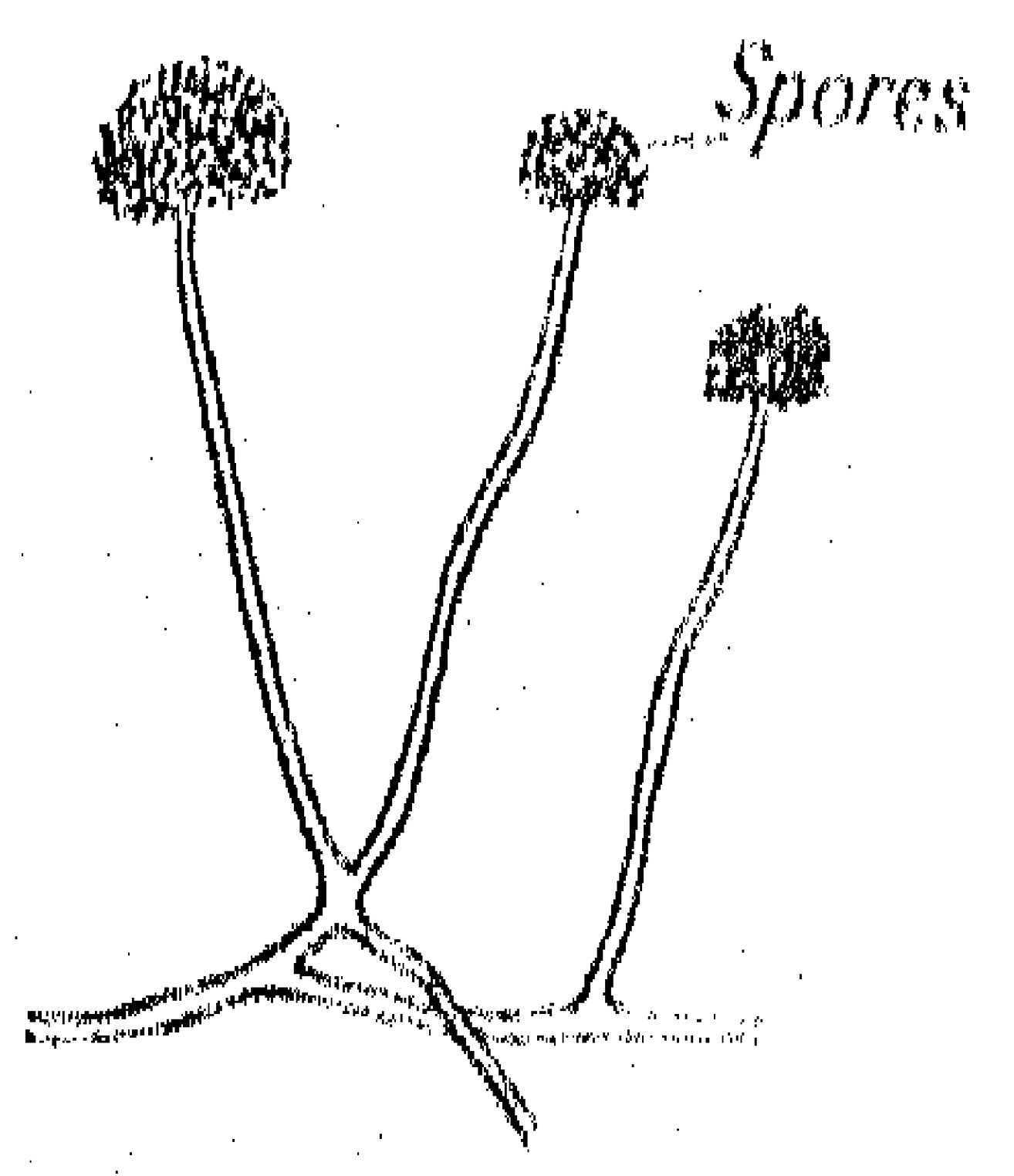

FIG. 28.—*Eurotium*, magnified.

Mushrooms and Toadstools

The moulds are all rather small, but there are larger kinds of fungi. Members of the group to which mushrooms and toadstools belong are known to everyone. The scientific name of this group is the *Basidiomycetes* (bay-sid-e-o-my-seet-eez). THE MUSHROOM will be described first and then a little will be said about some other members of the group.

The part of the mushroom eaten is only the fruit body with its stalk. The remainder of the plant comprises a mycelium consisting of many white hyphæ. It is this mycelium, usually growing in peat, which is sold by dealers as mushroom spawn, and *may* give you a crop of mushrooms if planted in the lawn. The mycelium lives in the soil, feeding upon decaying plant and animal matter just as *Mucor* feeds on potato or bread. If the weather and other conditions are suitable, the mycelium will finally produce the fruiting bodies or mushrooms. These usually appear, in the open, during late summer and autumn, but cultivated mushrooms can now be obtained all the year round. The mushrooms are composed of hyphæ tightly packed together to form a solid mass.

Mushrooms first appear above the soil as tiny white pear-shaped objects called "buttons" by the country folk. These grow very rapidly and in a few hours turn into the typical mushroom shape. The thick white stalk of the mushroom is continuous with the mycelium just below the ground. At its free end, the stalk bears the cap (Fig. 29*a*).

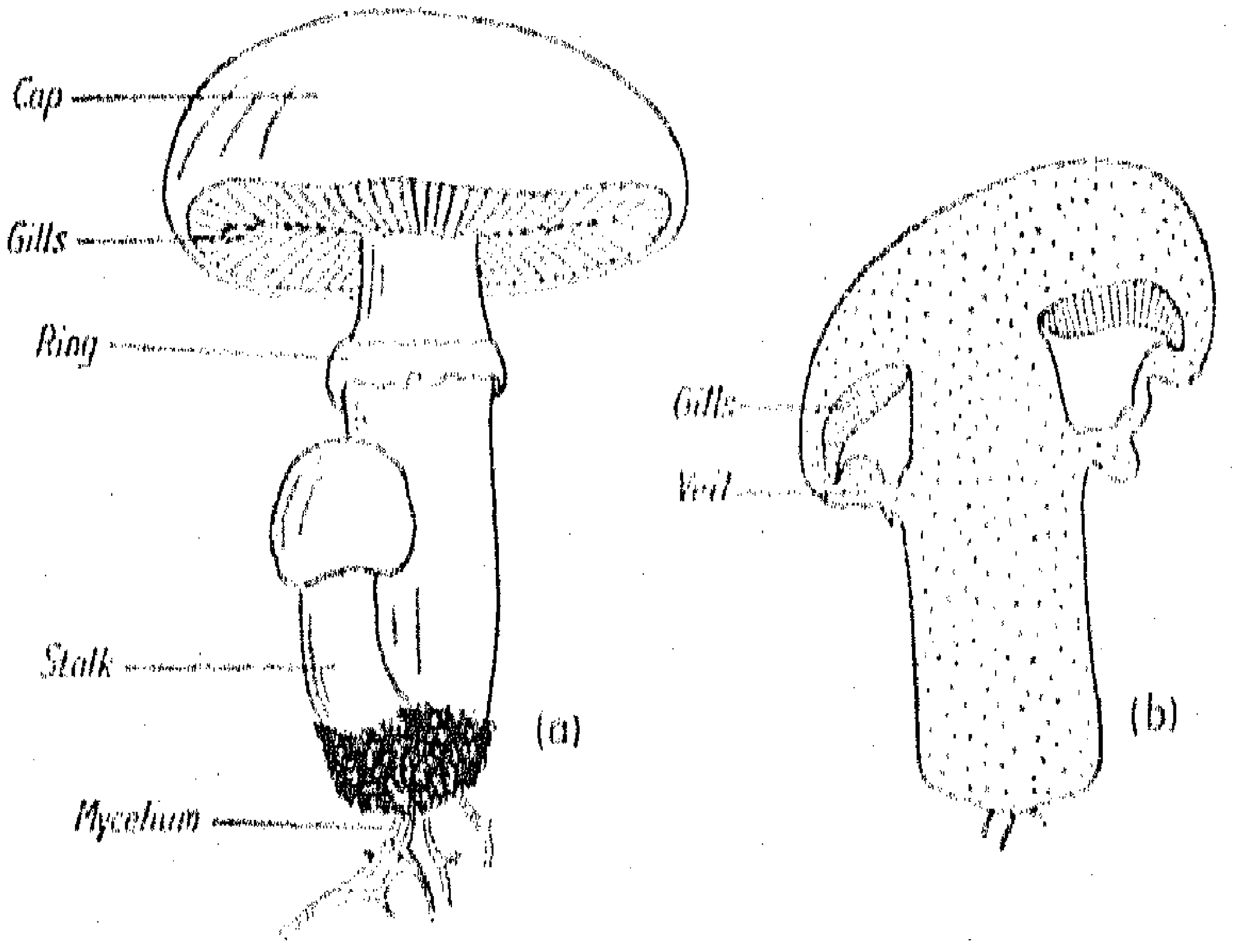

FIG. 29.—Common mushroom: (*a*) entire, and (*b*) longitudinal section of young specimen. (Both × 1.)

On its top surface the cap is gently rounded, but underneath it bears very many thin plate-like structures termed the gills. These radiate from the central stalk to the edge of the cap, like the spokes of a wheel. They are not fixed to the stem, but are joined to the cap all along their length. At first they are pink, but later become a dark brown and finally almost black. The spores are developed on the gills and the colour-changes of the gills are due to changes in the colour of the spores as they ripen. When the spores are ripe, they fall from the gills and are blown away by the wind, often for great distances. If

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a spore happens to fall on a suitable piece of ground, it grows into a new mushroom plant.

At the edge of the cap of a mushroom will be found fragments of a rather thin tattered membrane. This is called the "veil", and in the "button" stage it stretches across from the edges of the cap to the central stem to which it is attached (Fig. 29*b*). Consequently, at this time, the gills are shut off from the outside world and become visible only when the veil is torn as the mushroom increases in size. When that happens, the veil leaves a distinct ring of tissue round the stem.

The black spores of the mushroom are produced in great numbers, as you may easily prove for yourself by making a spore map. To do this, cut off the stalk of a young mushroom close to the cap. Then lay the cap with the gills downwards on a piece of white paper and place the paper in a cupboard where it will not be disturbed. Leave it for 24 hours. After this time, when you remove the cap, you should find the paper covered with spores, neatly arranged along the lines of the gills from which they have dropped. Sometimes there will be so many spores that they become piled up in distinct ridges.* The spores are extremely light, and if you find that air currents have spoiled the pattern, repeat the experiment, but, this time, cover the cap with a basin to prevent any air movements near the cap.

If you make spore prints of several different kinds of TOADSTOOLS, you will soon find that spores are not always black. They may be, according to the species, white, green, pink, brownish, or blackish purple, and it is not always possible to tell the colour of the spores from the colour of the gills. It is a good plan to make a collection of spore maps of different fungi, but, in order to keep them unspoiled, you will have to make them on waxed paper.

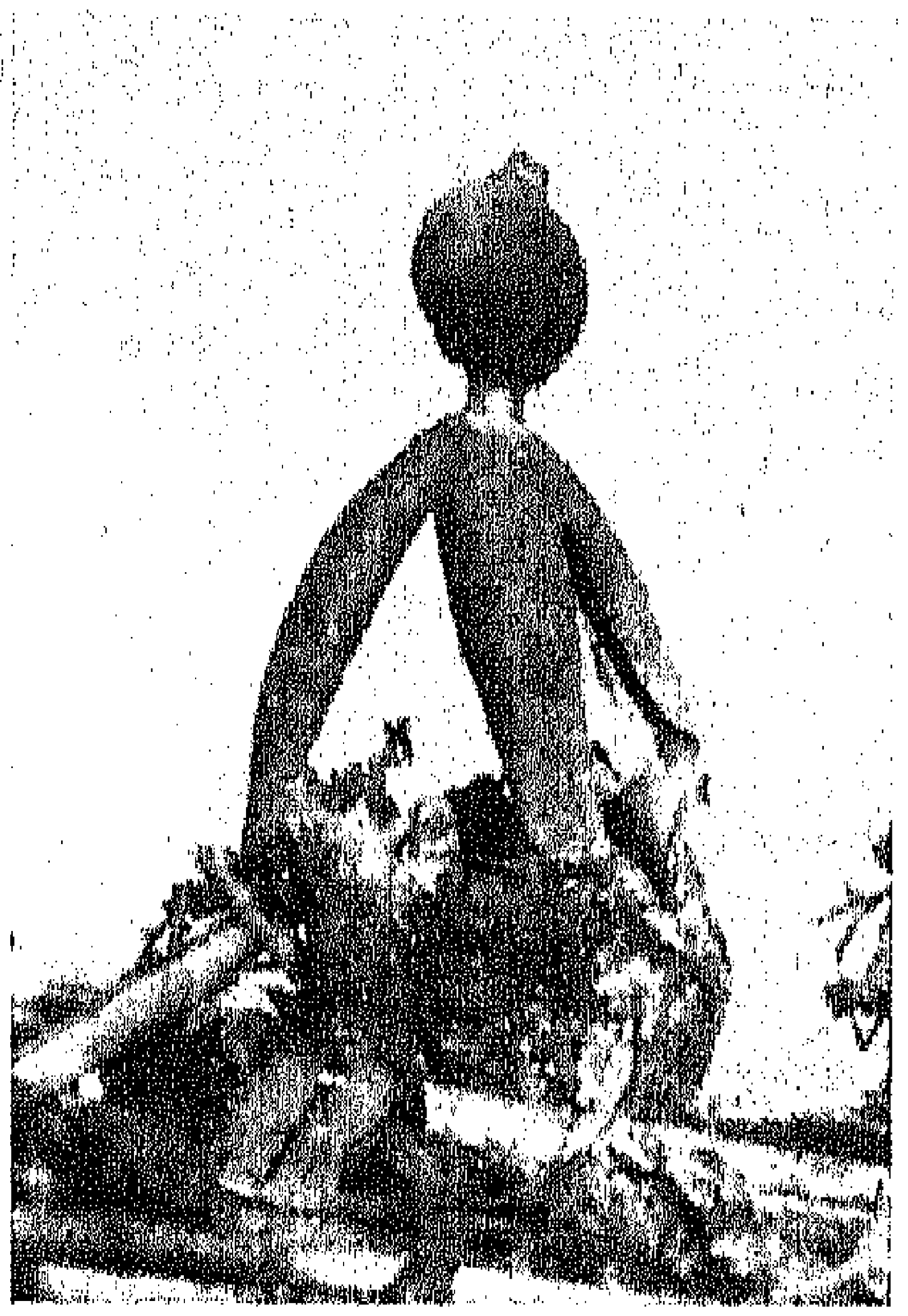
The waxed paper in which cornflakes are packed is excellent for the purpose. If this is not available, you can fairly easily make your own waxed paper.

To do this, melt a piece of candle wax in a wide tin lid or an old pan, and place in it a piece of paper. Ordinary drawing paper, or brown paper, serves quite well. When the paper has become thoroughly soaked in wax, remove it and allow the

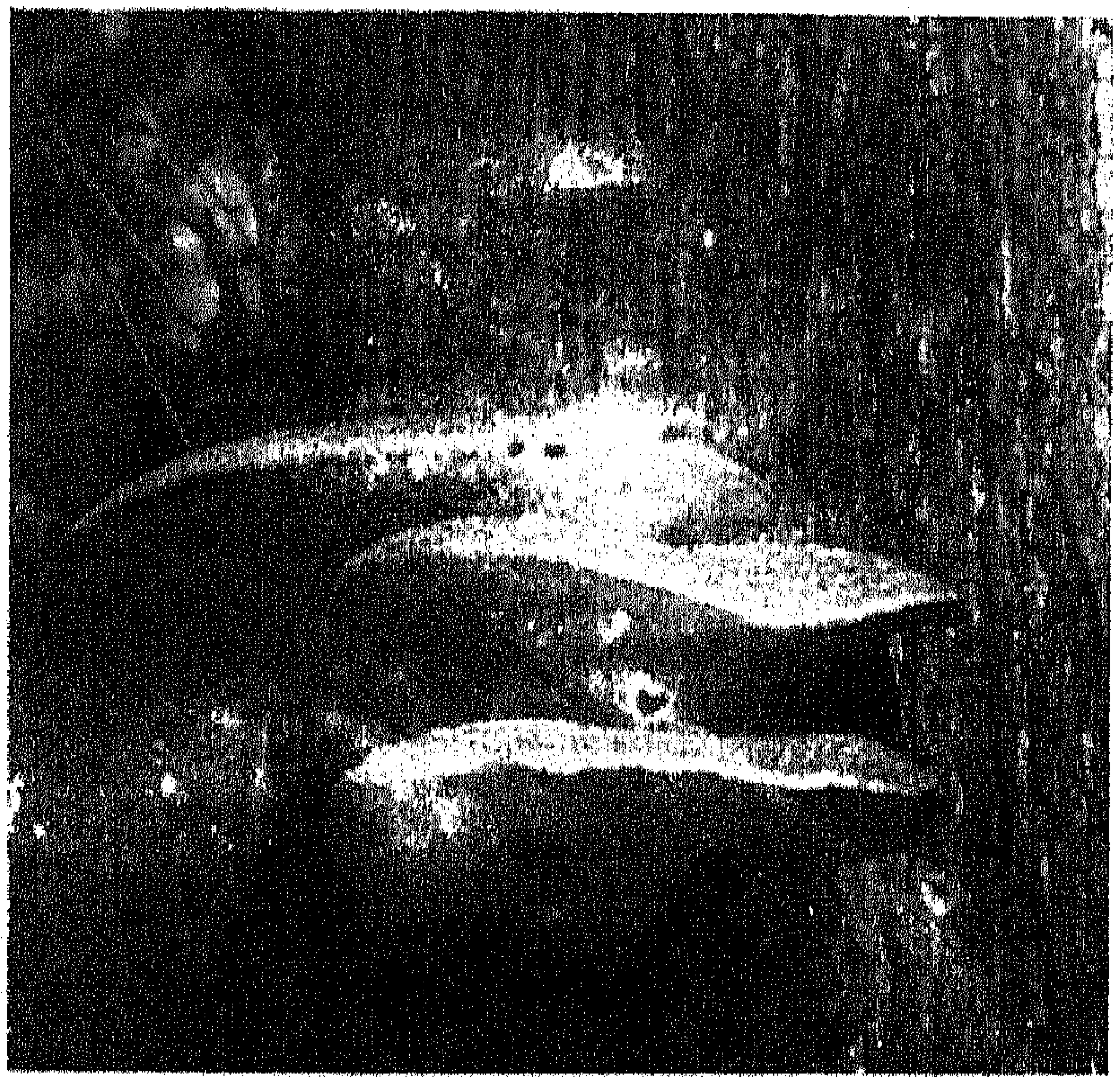
---

*It has been estimated that spores are liberated from an average-sized mushroom at the rate of one million a minute for about two days.

A. Bird's Nest Fungus (*Crucibulum vulgare*). The specimens in the foreground are immature, the "eggs" being covered with a silky down.



B. Earth Star (*Geaster fornicatus*).



C. A Bracket fungus (*Polyporus squamosus*) growing from the trunk of a dying elm tree. The top plate was 15 inches across. The fungus appeared year after year.

PLATE II

A.—Witches' Brooms growing on Silver Birch. The floor of the wood is covered with bluebells.

B.—*Coprinus micaceus* growing from the stump of a dying laurel. Note that some of the caps have been nibbled, probably by mice.

surplus wax to drain off. The wax left on the paper will soon harden.

Place your toadstool cap on this waxed paper and leave it overnight. Only a thin layer of spores is needed, and when this has been obtained take the paper with the spore print on it and warm it *cautiously* so that the wax just melts. A good place to heat it is on an electric hot-plate, with several thicknesses of newspaper between the hot-plate and the spore print. It may also be heated on a tin plate over a low gas flame, but here again you need several thicknesses of newspaper underneath the wax or it may be too strongly heated. If the wax becomes too "runny", or if there is too much wax on the paper, the pattern may be spoiled and you will have to start all over again, but if you are careful the spores will simply sink into the wax without moving about on the paper. Then, if you let the wax harden again, you will have your spore print "fixed" and you can keep it between the leaves of a book, or in your Nature Book if you keep one (as you certainly should). When you compare a number of spore prints, it will become obvious that the arrangement of the gills is not the same in all toad-stools.

Some toadstools, unlike the mushroom, do not have a ring around the stem (Plate II). Others, instead of having an umbrella-shaped cap, like that of the mushroom, have the cap hollow in the middle somewhat like an umbrella turned inside out, while others again have a long, more or less cylindrical cap rounded to a blunt point (Plate II).

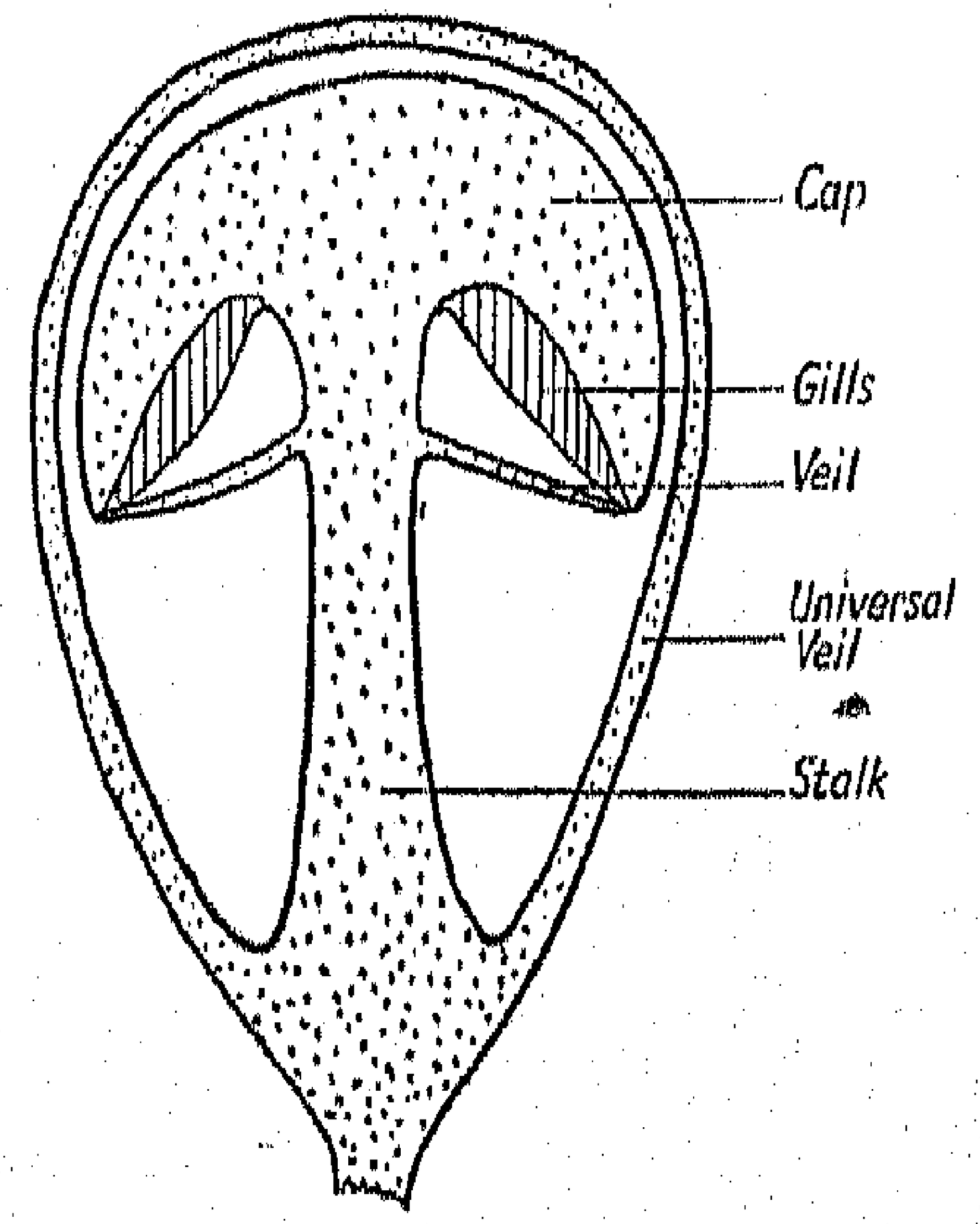


FIG. 30.—Diagram of longitudinal section through an "ideal toadstool" to show the nature of the universal veil.

Many toadstools, in the "button" stage, are completely covered by a membrane called the *universal veil* (Fig. 30). As the fungus inside grows bigger, this veil is torn. Part of it remains on the cap and splits into separate flakes, while the rest of it forms an irregular cup round the base of the stem.

This cup is called the volva. Those toadstools without a universal veil cannot have a volva. Some toadstools have both a ring and a volva, while others have neither.

Other Fungi

So far, we have discussed only those mushroom-like *Basidiomycetes* that bear their spores on gills underneath the cap. There are two other prominent kinds, the Spine-bearers and the Pore-bearers.

The general shape of the **SPINE-BEARERS** resembles that of a mushroom, except that underneath the cap there are no gills. Instead, there are very many small spikes which are closely packed together and may be up to 1 inch in length. The spores are produced on these spines. (Fig. 31 is a drawing of *Hydnum repandum* (hid-num re-pand-um) which grows on the ground in woods.) Some of the other Spine-bearers do not look like toadstools because they have no stalks. They grow as flat sheets closely pressed against the structure—usually the bark of a tree—on which they are living.

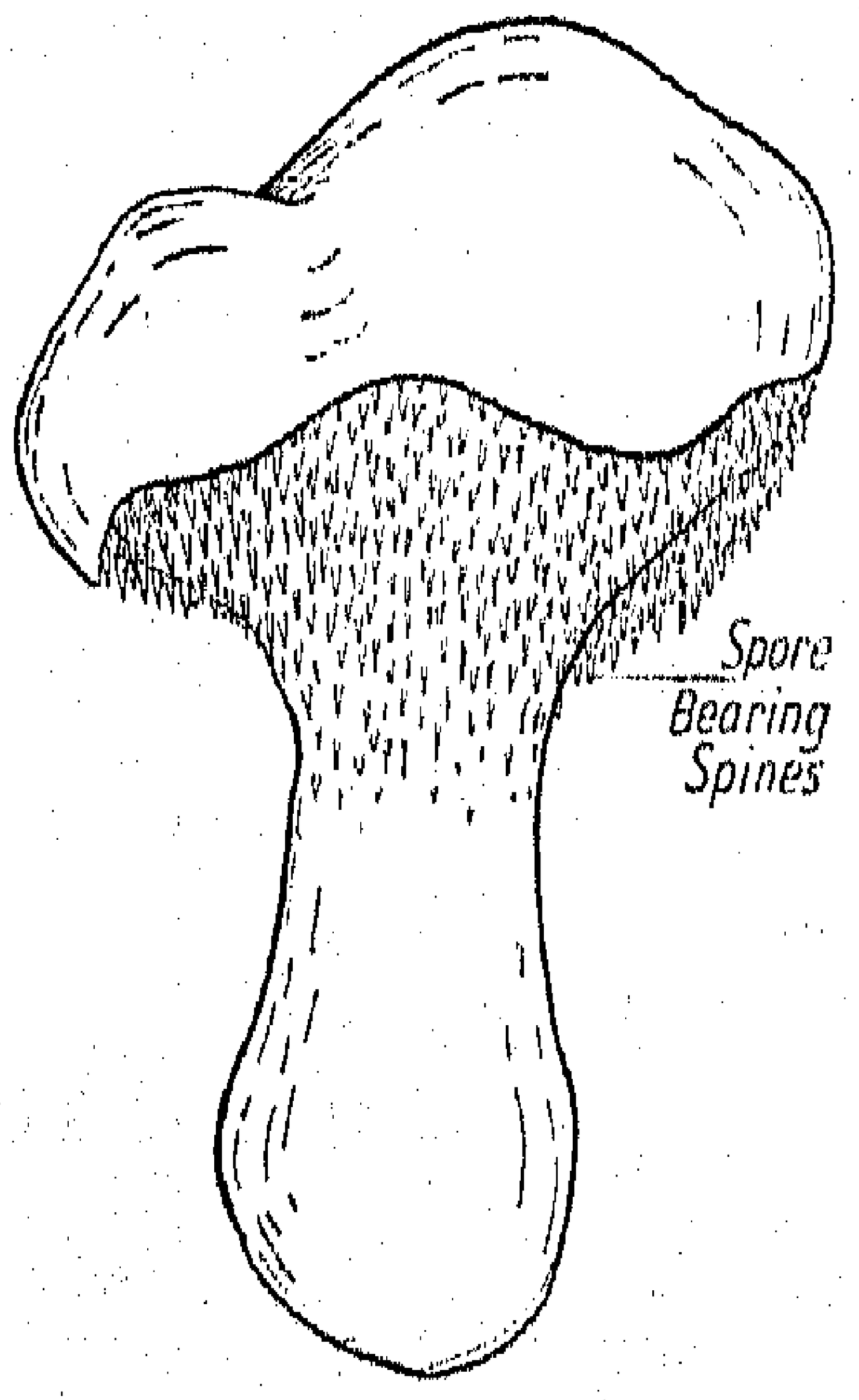


FIG. 31.—*Hydnum repandum*, a "spine bearer", ×½.

The **PORE-BEARERS** are easy to identify because in them the spores, instead of being formed on gills or spines, are produced in narrow tubes which open on to the surface-layer by small holes. Some of them look like toadstools, but, instead of gills being present under the cap, there are many tiny holes, each leading into a tube. The layer containing the tubes is easy to separate from the flesh of the cap. The common toad-stool-like Pore-bearers all belong to the genus *Boletus* (bo-leet-us), and in many of them the flesh of the cap turns blue as soon as it is broken and exposed to the air.

Other Pore-bearers have either a stalk at one side of the cap or no stalk at all. The conspicuous ones of this group are the **BRACKET FUNGI** that grow out like small shelves from the trunks of trees. The mycelium of a bracket fungus is inside the tree and, in time, will kill it. The structure is much the same in all cases. There is a fairly thick cap which may be quite hard, leathery, or soft, and, underneath it, is a layer with the tubes that contain the spores (Plate I).

Some bracket fungi remain for many years in the same place, but others grow out from the trunks of trees within a few weeks, shed their spores, and wither away soon afterwards. You may often see bracket fungi growing on trees in towns. Elm and birch trees in particular seem often to be attacked.

All the above fungi have the structures that bear the spores freely exposed to the air. In the **PUFFBALLS** and **EARTH STARS** this is not so. Most people have, by squeezing a puffball, made it emit puffs of "smoke". The "smoke" is really a cloud of spores, and you will get some idea of the enormous number of spores produced by these fungi if you obtain a puffball and keep on squeezing it until it no longer smokes—if you can!*

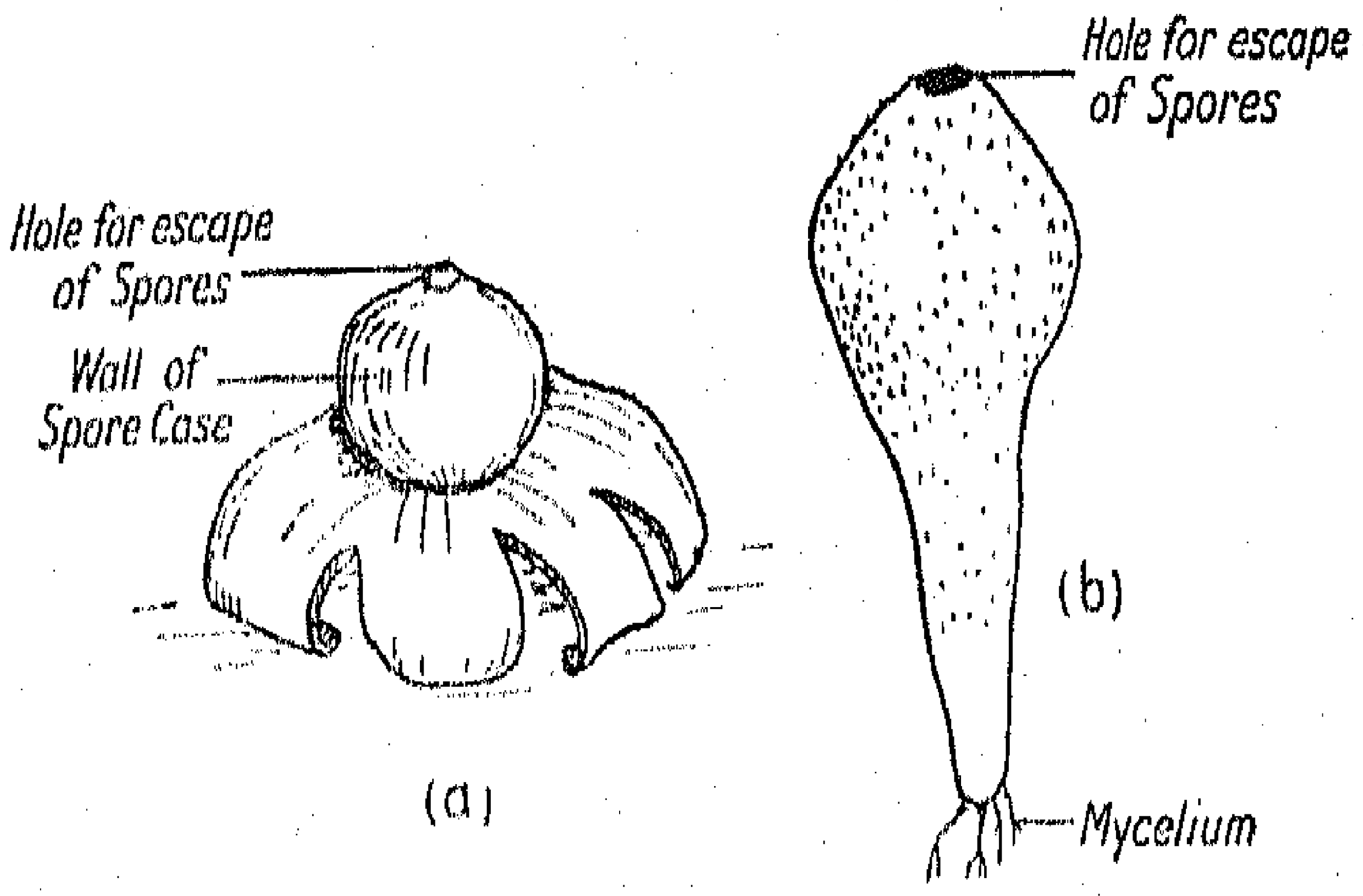

Hole for escape of Spores
Wall of Spore Case
(a)
Hole for escape of Spores
(b)
Mycelium

FIG. 32.—(*a*) Earth Star, *Geaster fimbriatus*; (*b*) Puffball, *Lycoperdon piriforme*. Both slightly reduced.

The young puffballs are white, pear-shaped structures, with a rather warty skin. If you cut a young one across with a knife, you will find a jelly-like mass inside. This will ultimately give rise to the spores. As the puffball ripens, it gradually dries and turns brown, and an opening appears at the top through which the spores escape (Fig. 32*b*).

The **EARTH STARS** are rather like the puffballs, but much rarer. They differ in that the wall is divided into three layers when they are ripe. The two outer layers split into several leaf-like portions and spread outwards so that they resemble a star. The inner wall remains to enclose the spores which escape from a hole at the top (Fig. 32*a* and Plate I).

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* The Giant Puffball is said to produce seven million million spores!

Also belonging to this group are the stinkhorns, of which the **Common Stinkhorn** can often be found under trees where there is much rotting material. When ripe, a Common Stinkhorn has the shape shown in Fig. 33. The white stalk, which is rather brittle, bears a thimble-shaped structure at its tip. This is thickly covered with an olive green slime, and has a very unpleasant smell (hence its name). The slime, however, is very sweet to taste, and mixed up with it are the spores. Flies are attracted to the stinkhorn by the smell and feast upon the sweet slime, and, when they fly away, carry some of the spores sticking to their bodies.

If you dig up a Common Stinkhorn, you will find attached to the volva at the base a number of white cords which spread away into the surrounding soil. These white strands are part of the mycelium of the Stinkhorn and usually they have attached to them several white rather elastic structures resembling "eggs" of various sizes. The "eggs" are young Stinkhorns, and, if you cut one down the centre with a sharp knife, you will be able to see the developing Stinkhorn inside, surrounded by a thick layer of jelly.

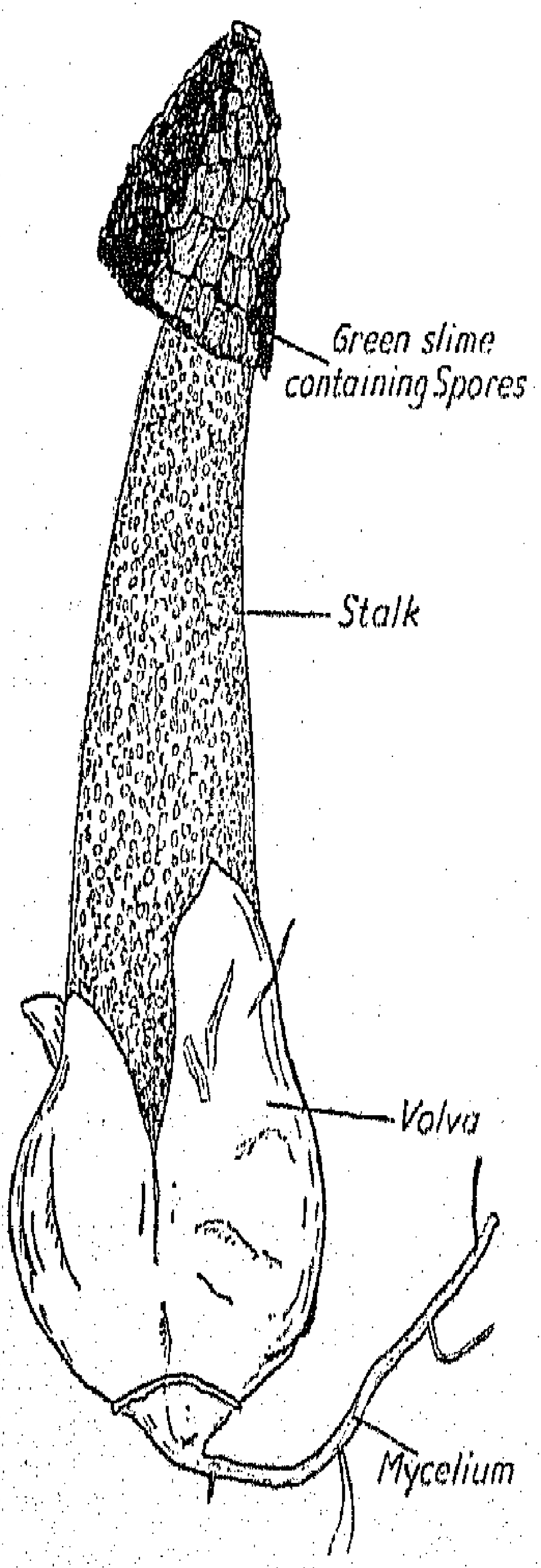


Fig. 33.—Common Stinkhorn, *Ithyphallus impudicus*, ×½.

It will be seen that the fungi form a most interesting group of plants. Their body walls are made of a different material from the cellulose that forms the body walls of other plants (cotton wool is pure cellulose). Fungi never contain the green colouring matter *chlorophyll* (klor-ro-fil) which enables other plants to make their own foods. Hence fungi require a supply

of ready-made food. This they absorb through the tips of the hyphæ forming the mycelium. Some fungi obtain their food from the dead bodies of plants or animals, or from non-living products of plants and animals (e.g., cheese), making the material soluble, if necessary, by means of special chemicals produced by the hyphæ. Such fungi are called *saprophytes* (sap-ro-fites) and this particular way of life is called *saprophytic*. Other fungi obtain their food directly from the *living* bodies of plants and animals, usually causing serious harm to the organisms they attack. Such fungi are called parasites. Both the parasitic and saprophytic modes of life are found in other groups of organisms.

There are numerous other fungi in addition to the types already outlined. A whole host of small forms are parasites, among which may be mentioned the blights and mildews that attack garden crops, and the rusts and smuts, some of which attack cultivated grain. Ringworm is caused by a fungus that attacks the skin of the scalp, while yeast—used for brewing and bread-baking—is another small fungus. A study of these forms requires a microscope and is beyond the scope of this book.

"Witches' Brooms" and "Fairy Rings"

Two interesting things you will come across on country walks are "witches' brooms" and "fairy rings". Both of these are caused by fungi.

A "witches' broom" is the name given by country folk to the dense clusters of small misshapen branches that occur on certain trees, especially birch trees (Plate II). The mass of thin twigs may be not much bigger than a tea-cup, or it may be very large and look like a crudely built nest of some large bird. These structures are similar in nature to the galls discussed in chapter 28 (p. 284), and are the tree's response to the presence of a very tiny fungus growing upon it. It used to be believed that witches' brooms grew only on trees witches had flown over on their broomsticks during their nightly rides.

"Fairy rings" are found in grass fields and are most conspicuous in autumn. They are circles of brighter green grass, the circles sometimes being four or five paces across, but often less. Frequently you will find toadstools growing round the ring, and these, in the case of any one ring, will be all the same kind. The old belief is that the fairies dance round the ring at night and use the toadstools to sit on when they are tired. It is often possible to see a more or less bare circle running through the ring of greener and taller grass, as if a track had indeed been worn bare by the feet of circling fairies.

However, it is now known that the rings increase in size year by year, and that they are caused by the mycelium of the fungus whose fruiting bodies are to be found round the ring. The mycelium originally started as a spore at one point and from there gradually spread outwards in all directions among the grass roots. This accounts for the circular shape. Immediately beyond the zone where the mycelium has reached, the grass grows more lush, probably stimulated by substances given off from the tips of the hyphæ. The grass is killed immediately above the perimeter of the mycelium and this causes the bare patch. The grass has grown again inside the fairy circle, for it seems to be only the tips of the hyphæ that are harmful.

CHAPTER SIX

Fishes

A Sea Fish—The Herring

THE HERRING has been chosen as my main example of a fish because it is fairly large and can also be obtained cheaply at most seasons of the year.

In colour, a herring is a dark metallic blue on its upper surface but the blue gradually merges through light brown on the sides to a silvery white on the ventral (underneath) surface. Very many other fishes have a similar dark coloured back and a silvery belly. This kind of shading helps to make them difficult to see in the water, as is explained on p. 212.

The first thing to strike one about the shape of the herring is the smooth outline of the body, whose depth from the dorsal (top) surface to the ventral surface is greater than the width from side to side. From the pointed snout, the sides of the body curve gently backwards and outwards to the thickest point of the body, about one-third of the distance from the head to the tail. From here the body gently narrows to the tail. Such a body is said to be streamlined and its shape helps to reduce the resistance offered by the water to motion.

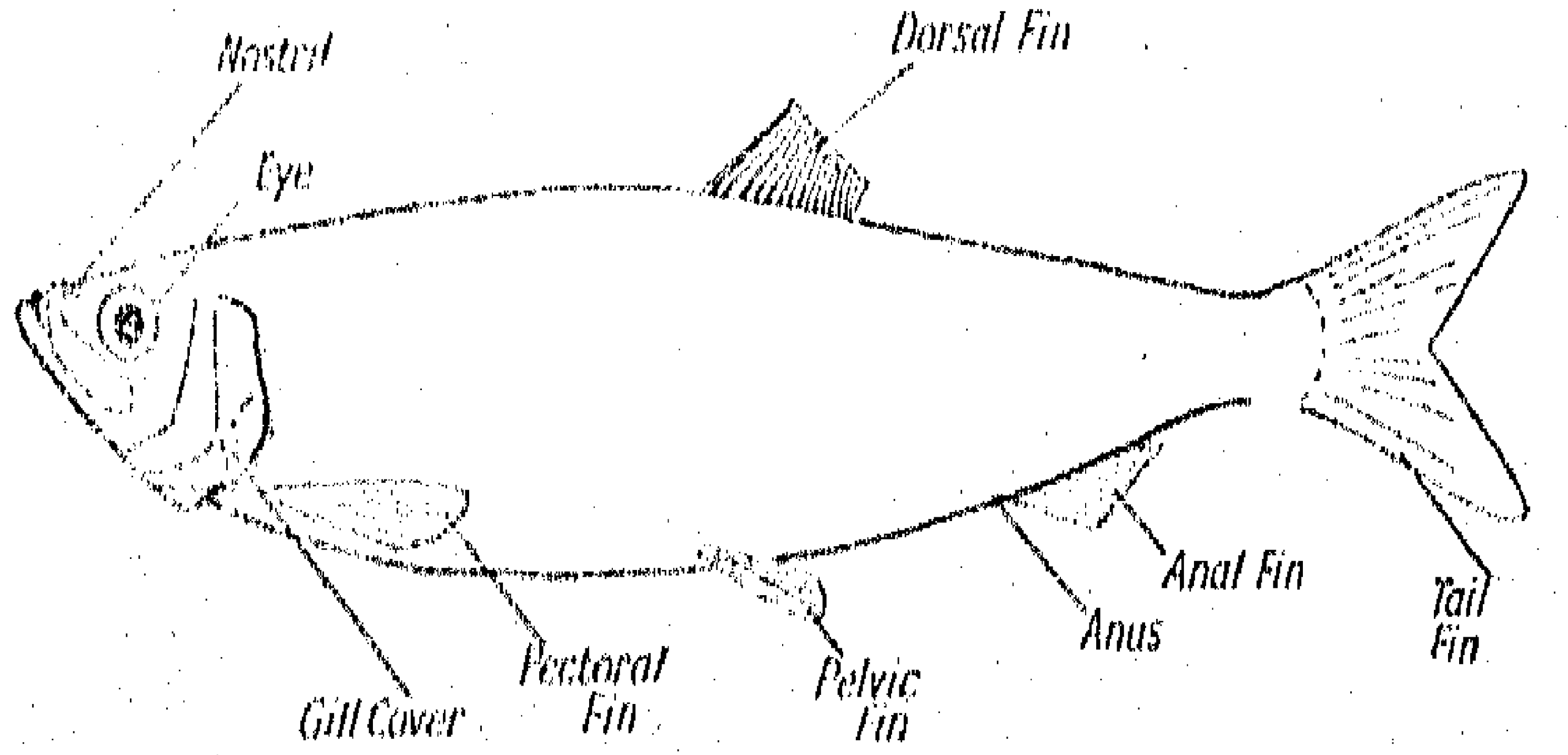


FIG. 34.—The herring, ×½.

With the exception of the head, the body is completely covered by numerous scales which overlap one another somewhat like the tiles on the roof of a house, though fish scales are more or less circular in shape. The scales are embedded in the skin but can easily be scraped away, and, indeed, many will be found to be loose on purchased herrings.

The mouth of the herring is at the extreme front of the body. Normally, in dead fishes it is closed or only slightly open, but by pressing down on the lower jaw you will be able to open it quite wide. Inside the mouth will be seen the tongue, and behind that a number of whitish processes pointing forwards and looking rather like the teeth of a comb. These are the gill "rakers" that help the herring to filter food particles from water taken in through the mouth. The tip of the lower jaw has a number of fine teeth which can be felt by drawing the finger gently over them. The sides of the head and jaws are supported by bony plates. Those supporting the jaws can move on one another because they are connected together by pliable membranes.

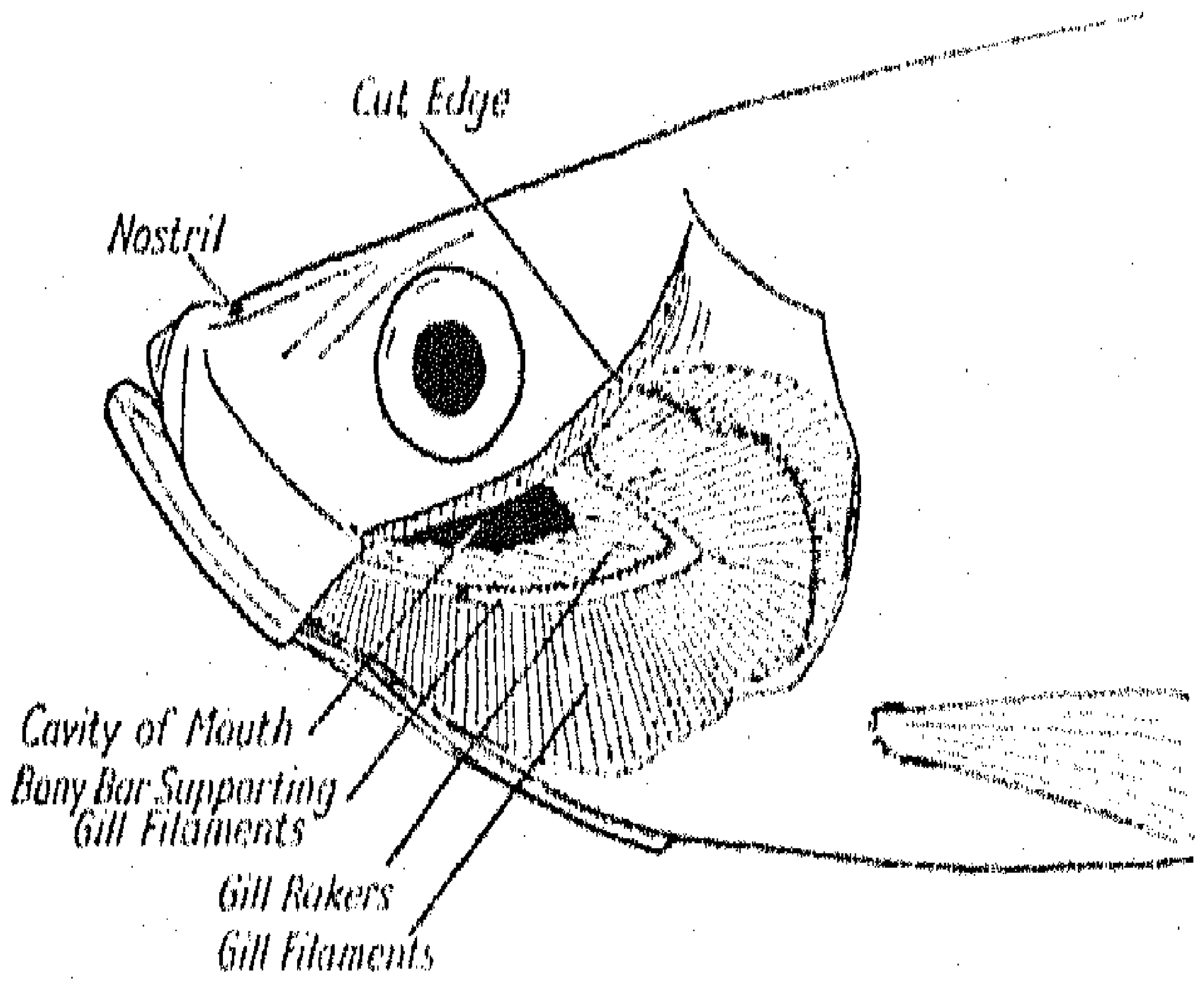


FIG. 35.—Head of a herring, with the operculum removed from the left side to display the gills, × 1.

On top of the head are two small holes, which are the nostrils (Fig. 35). Behind and below them are the prominent eyes, usually coloured more or less red. The outer surfaces of the eyes are much flatter than in humans and other mammals, and there are no eyelids in fishes so that the eyes cannot be closed. The black disc in the centre of each eye is the pupil through which light actually enters the eye.

Where the head joins the body there is a movable flap on each side called the gill cover. When one of the gill covers is lifted, the gills will be seen lying underneath. Each gill consists of a U-shaped hoop of bony material to which are attached many delicate filaments lying side by side like the teeth of a very fine comb (Fig. 35). In living or freshly killed fishes the gill filaments are a bright red colour on account of the blood they contain; but after death the colour soon changes to a dull chocolate brown.

There are four gills on each side, situated one behind another, as you may easily verify by lifting them. There is a passage way between each gill and the next, which leads into the mouth cavity. It follows from this that a pencil can be pushed through the gill clefts from outside to come out through the mouth.

The gills are the breathing organs of the fish and do the same work as our lungs. During its life, the herring continually gulps water into its mouth and passes it over the gills and out from under the gill covers. As the water passes over the gill filaments, some of the oxygen dissolved in it passes through their walls into the blood they contain, and carbon dioxide passes out from the blood into the water. The respiratory movements can be best observed in fishes kept in aquaria.

About one quarter of the way along the herring's body from the tail end there is a small hole in the mid-line of the ventral surface. This is called the anus and is the hind end of the food canal. Through the anus waste matter is passed from the fish's body. The reproductive cells, eggs or sperms as the case may be, are liberated from a small aperture behind the anus.

The region between the anus and the end of the body is called the tail and it ends in the tail fin, a flexible sheet of material supported by many fine stiff rods, the fin rays.

Apart from the tail fin, there are six other fins on the body of the herring. All have a similar structure, that of a sheet of membrane stiffened by fin rays. On the back of the fish, just behind the mid-point, is the dorsal fin. In a dead fish this will be folded along the body but it can easily be pulled up to the position shown in Fig. 34. This is the position it has in a live fish. The fin rays of this dorsal fin will each be seen to divide into four branches near the free end, while the fin itself is covered with fine black dots.

Just behind the anus is another fin, also in the mid-line of the body. This is called the anal fin. The pair of pelvic fins are situated on the ventral surface at about the mid-point. The remaining two fins are found, one on each side, just behind the gill covers. They are called the pectoral (pek-tor-al) fins.

The fins are used to enable the fish to keep its balance when it is moving through the water. They do not assist in the swimming movements to any extent. Power for forward movement comes only from the tail as it is swept from side to side.

Do not throw the herring away as soon as you have examined and drawn it, and after a day or two look at it in the dark. You are almost certain to find that it is glowing with a cold mysterious light. This *phosphorescence*, as it is called, is caused by the activities of certain bacteria, much too small to be seen without a powerful microscope.

A Freshwater Fish—The Stickleback

The STICKLEBACK (often known as the "tiddler") is the smallest British freshwater fish. Most ponds, ditches, rivers, and the like, contain sticklebacks, which seem to be able to live in water that is unsuitable for other fish. The Common Stickleback has three prominent spines situate along its back, and from these it gets its name. The males fight a good deal among themselves, and often, if several are placed together in an aquarium, one will kill the others. Female sticklebacks are usually rather larger than the males.

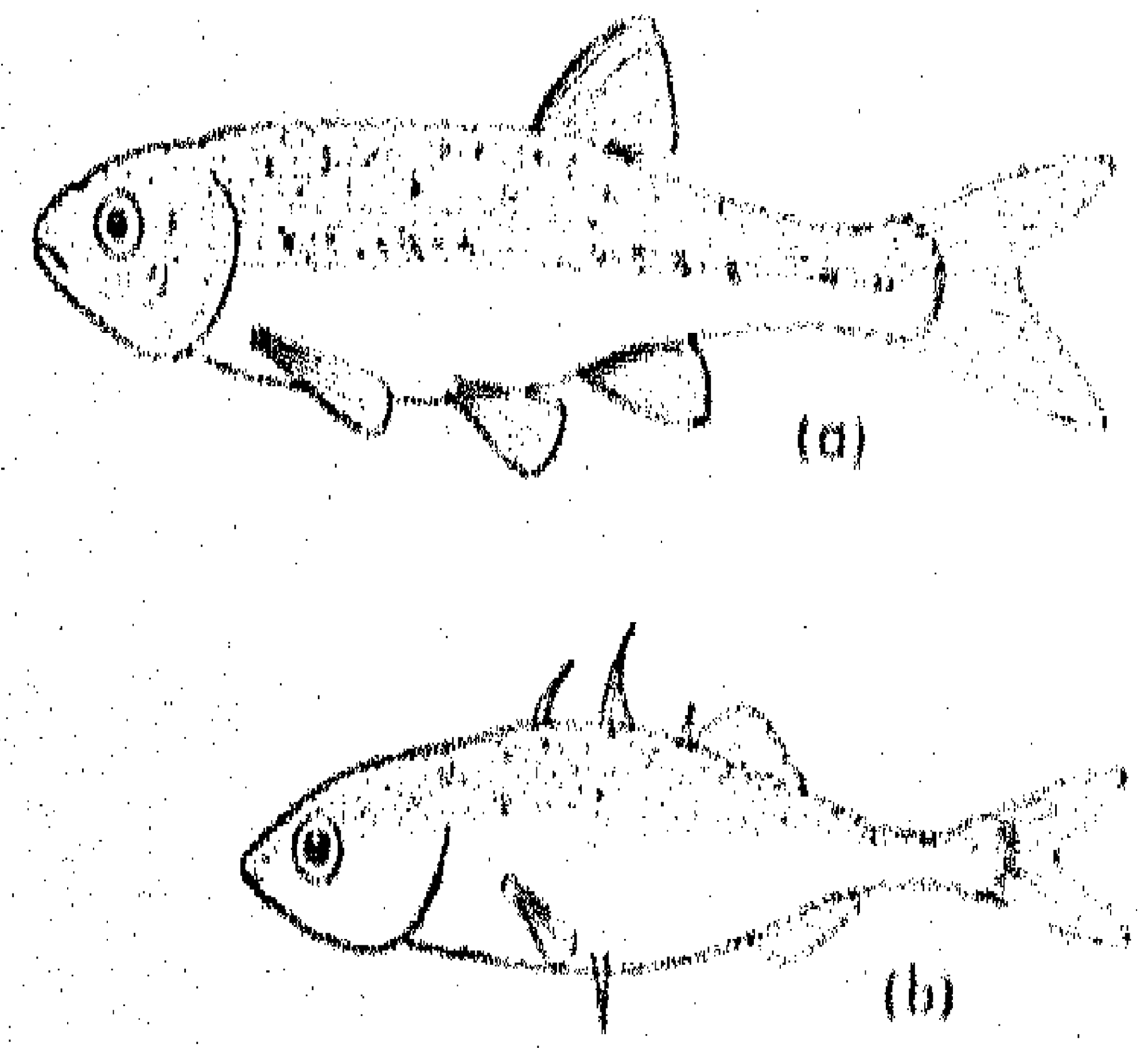


FIG. 36.—(*a*) Minnow; (*b*) Three Spined Stickleback. Both slightly enlarged.

In spring, as the breeding season draws near, the breasts of the males become a vivid red, and such fishes are known as "red-breasts" or "red-throats". A "red-breast" is a particularly interesting fish because it builds an underwater nest from bits of pond weed and other plant material that it can carry in its mouth, gluing the pieces together with a substance made by the kidneys and passed out from the urinary pore behind the

anus. The nest is built in a shallow depression on the bottom and looks rather like a tiny straw barrel about 1 inch long.

When it has completed the nest, the male stickleback persuades a female to enter it through the opening left in one side, and to lay eggs in it. After she has done this, the female bursts her way out through the wall opposite to the opening through which she entered and swims away. Then the "red-breast" persuades other females to come and lay more eggs, and not until there are between fifty and one hundred eggs is he satisfied. No doubt the red colour developed on the breast of the male makes him more attractive to females and helps him to persuade them to enter his nest to lay eggs, though he will use force, if necessary. After the eggs have been laid, the male stickleback sheds male cells (sperms) over them. Each egg has to be fertilised by a sperm before it can develop into a young stickleback.

The "red-breast" does not desert his nest as soon as the eggs are fertilised, but remains near it on guard, ready to dart out and attack intruders that might destroy the eggs. He will even replace eggs that get dislodged from the nest, and remove dead ones that go mouldy. The female sticklebacks themselves would eat the eggs if they had a chance. By fanning with his tail the "red-breast" causes a current of water to move through the nest, in at the mouth and out through the opening that was made by the females in the opposite wall. In this way a constant supply of oxygen is brought to the developing eggs which, because they need plenty of oxygen, would soon exhaust that dissolved in the water around them if that water remained still. The male stickleback guards the nest until the eggs hatch and continues to watch over the young for a few days until they are more able to take care of themselves.

Another small freshwater fish, sometimes mistaken for a stickleback, is the minnow. It can easily be recognised, however, for it has no spines along its back. Minnows do not like still water and prefer fairly rapidly flowing streams.

When you go "tiddler" hunting you may occasionally catch a Ten-Spined Stickleback, which, as its name suggests, has ten slender spines along the back in place of the three stout ones present in the Common Stickleback.

Fishes live on a great variety of food, including plant matter, small water animals, worms, and even other fishes. In winter, with the dying away of the water plants, food tends to become scarce, and a number of British fishes, such as carp, tench, and bream, bury themselves in the mud at the bottom of the pond or stream and stay there during the cold winter months. Sticklebacks and minnows do not bury themselves, but withdraw to the deeper water and almost cease to feed.

Fishes that live in both Sea and Fresh Water—Eels and Salmon

To conclude this chapter, mention must be made of the peculiar journeys undertaken by eels and salmon for the purpose of breeding. **Eels** live in ponds and rivers until they are about nine years old. Then a strange desire to go down to the sea takes hold of them, and away they go. If they are in ponds with no outlet, they will crawl out and slither across country making use of ditches and other damp places, until they finally reach a river. Then they swim down the river to the sea and away across the ocean to a point in the Atlantic near the Sargasso Sea where it is very deep (Fig. 37). There at the bottom they breed, and then they die. From the eggs, young are hatched which do not look at all like eels, but are tiny, flat, almost transparent, creatures. These set out on the return journey to England, taking nearly three years to arrive at our rivers. By this time they have turned into tiny eels called elvers. The elvers swim up the rivers and in time grow into adult eels which, in their turn, will undertake the long journey to breed and die.

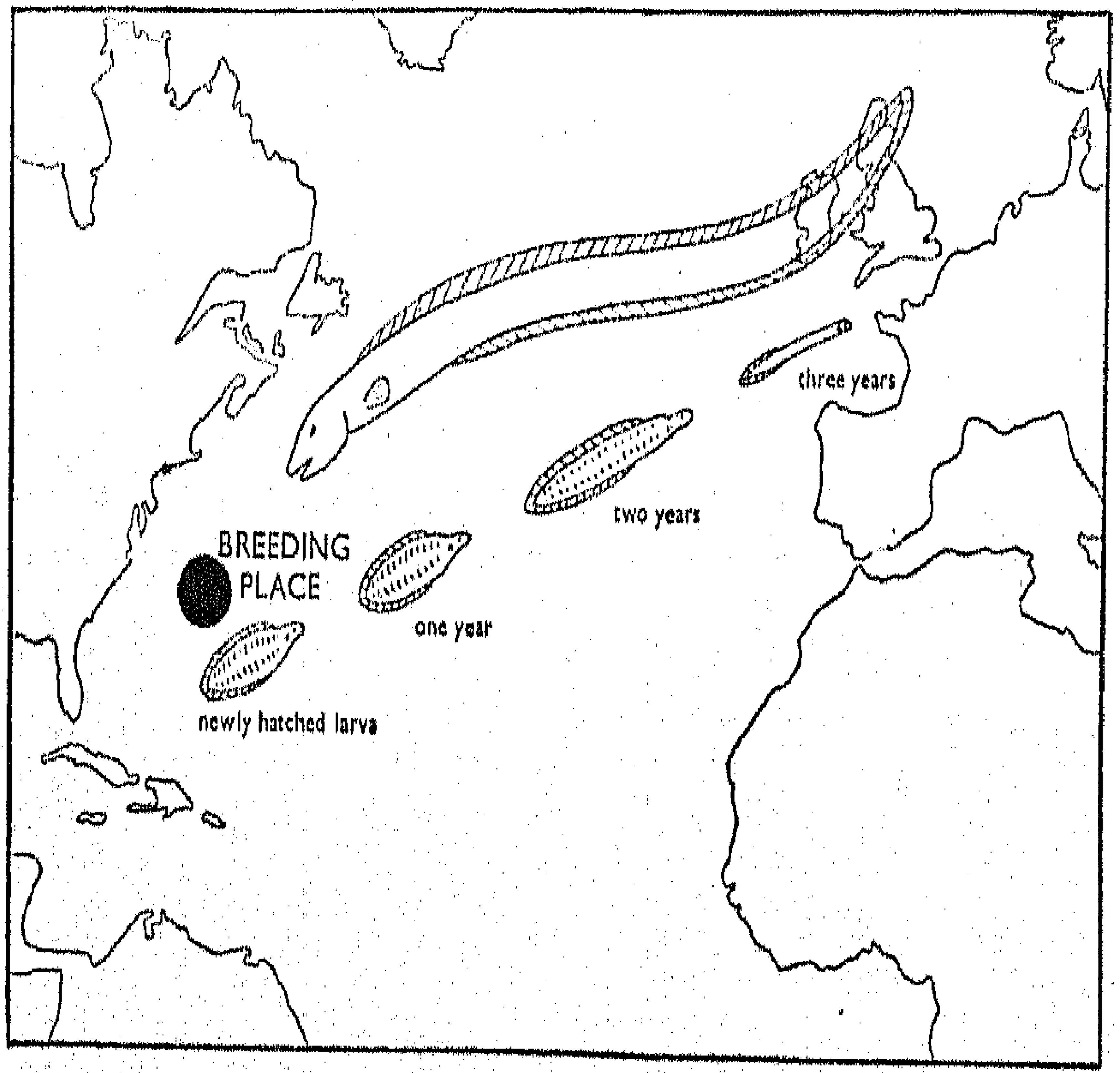


Fig. 37.—Life cycle and breeding migration of the Eel. The adults swim to the region marked by a black circle, lay eggs or sperms, and die. The larvæ, at first flat transparent creatures, take more than two years to gain the European coast, when they have the form of elvers. The elvers ascend the rivers in vast numbers.

Salmon also make a long journey to breed, but in their case it is from the sea into the rivers. The salmon grow to maturity in the sea and then move into mouths of rivers around our coasts. From here they make their way up to the head-waters of the rivers, often performing remarkable leaps to surmount waterfalls. In the little streams near the sources of the rivers the females make shallow troughs in the sandy bottom, and there lay their eggs. The males then lay sperms over the eggs to fertilise them, and the excited movements of the fish cause the eggs to become covered with sand. Here they develop into young salmon, or fry as the very young fish are called. The fry spend two years in the rivers before going down to the sea where they grow into adult salmon. The parent fishes do not live long after breeding, although they may return to the sea. Such exhausted salmon are called "kelts".

CHAPTER SEVEN

Newts, Frogs, and Toads

Newts

THERE are three species of newts in Britain, the Common Newt, the Great Crested Newt, and the Palmate Newt. I shall describe the structure and life-history of the Common Newt which in the eastern part of England is the most abundant species, though in the west the Great Crested Newt and the Palmate Newt are more common.

Newts, like toads and frogs, breed in water, and there they may be caught in nets during the breeding season (April, May, and June). As a rule they do not stay in the water after the breeding season, and towards the end of summer may be found under stones, decaying logs, piles of rotting vegetation, and suchlike places, in the neighbourhood of ponds. Often at this time newts will be discovered at some distance from water. I frequently come across them in autumn when I am searching for beetles. As a youngster I used to catch newts in the pool of an old quarry during the breeding season, by tying a small lively worm to a piece of fine string and throwing the worm into the water. It would be seized by a newt which could then be hauled out because it refused to let go.

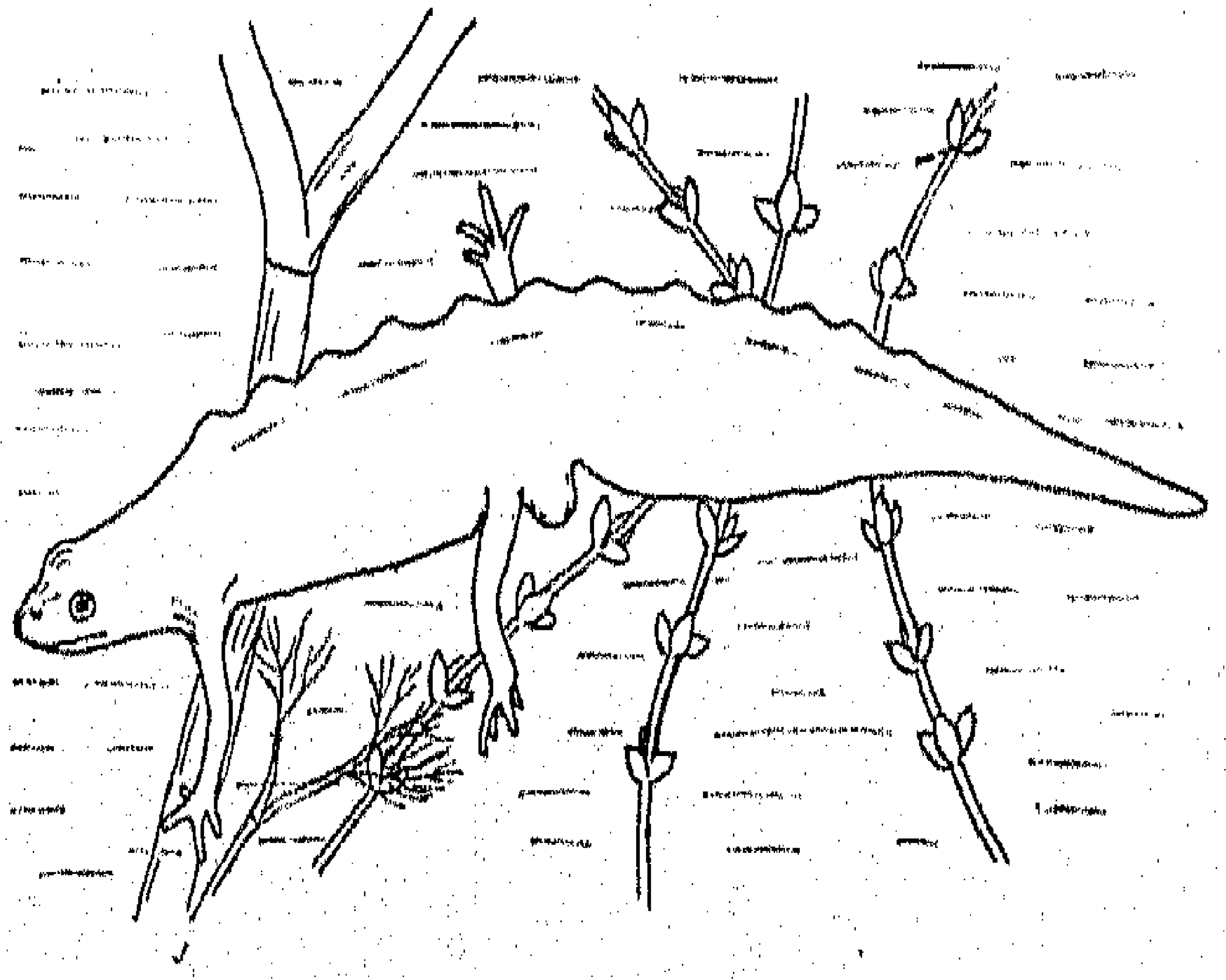


FIG. 38.—Male of the Common Newt, × 1. The plants shown are (*left*) Water Crowfoot, and (*right*) Canadian Pond Weed.

The Common Newt (Fig. 38) is about 4 inches long when fully grown and is shaped rather like a lizard, but differs in that the skin is soft and moist to the touch. The general colour is a dark greenish brown with darker spots or dashes. The under surface is usually reddish orange with a number of round dark spots, though in females the spots may be absent and the colour of the belly is paler than it is in the males. The underside of the throat is whitish or yellowish with a sprinkling of black dots.

The mouth is wide and slit-shaped and inside, round the edges of the jaws, are many very tiny teeth which point backwards and are used for holding the live prey which consists of worms, insects, and other small creatures. On the head is a pair of nostrils placed well to the front above the snout, and two eyes situated on the sides of the cheeks. There are no signs of external ears.

The head is continued into the body with hardly a trace of a neck. On the body are two pairs of legs, but these do not lie directly under the body, as they do in dogs, cats, and other mammals, but stick out sideways so that newts have a sprawling method of walking which is most ungainly. Each limb corresponds roughly to the human limb, with two main joints and at the end a hand or foot as the case may be. On each front limb there are four fingers but on the hind limbs there are five toes. The fingers and toes end in blunt knobs and there are no traces of claws.

In the mid-line of the ventral surface, a short way behind the hind limbs, is an opening called the *cloaca* (klo-ay-ka). Through this cloaca a newt gets rid of its waste matter and also passes out the reproductive cells, the eggs in females and the sperms in males (see p. 279).

Behind the cloaca the body continues as the tail. This is almost as long as the rest of the body and is flattened from side to side. It is by moving its tail that the newt is able to swim.

Male and female newts differ from one another, especially in the breeding season when the male develops a showy breeding crest along the mid-line of the back. The crest, a thin fold of skin, runs from the head to the end of the tail, and its top edge is wavy in outline. At this time, too, the orange belly surface of the males become much brighter in colour.

During the breeding season the newts live in water. The colours of the male grow more vivid and the crest becomes fully developed. The male then tries to interest the female by showing-off his colours and crest, and butting her sides with his snout. After a period of this courtship, he lays one or two small transparent jelly-like packets of male reproductive cells (sperms). Each packet is shaped something like a mushroom and is quite big enough to be seen with the naked eye, being about one quarter the size of a match head. The sperm packets fall through the water to the floor of the pond and are picked up by the female with the lips of her cloaca. Inside her cloaca the sperms are set free and swim up the egg tubes where ultimately one sperm joins with each egg present in the female to fertilise it. The female then lays her eggs, usually placing them one at a time on the surface of an underwater leaf and bending the leaf over. As the eggs are sticky, the leaves remain curled over them. Sometimes, however, I have had Common Newts lay eggs in strings or ropes containing many eggs. It is true that this has always occurred when the newts were kept in shallow dishes of water, not in deep tanks with water weeds growing from the bottom.

After they have completed breeding, Common Newts leave the water and live for the rest of the year on land. During the day they remain hidden in places where there is plenty of moisture, for on land they are always in danger of drying up because their skins are not "watertight". After the newts have been on land for a short time, their skins darken and take on a glossy velvet appearance.

The eggs are left to themselves in the water, and hatch in about a fortnight. From each egg there emerges a tiny creature called a larva, a delicate transparent animal which really is quite beautiful to watch. The larvæ have the general shape of the adult newts, but as yet have no legs. Further, growing from each side of the head is a tuft of feathery gills (Fig. 39). Actually each tuft consists of three separate gills. Through these gills the young newts both obtain oxygen from the water where they live, and expel carbon dioxide.

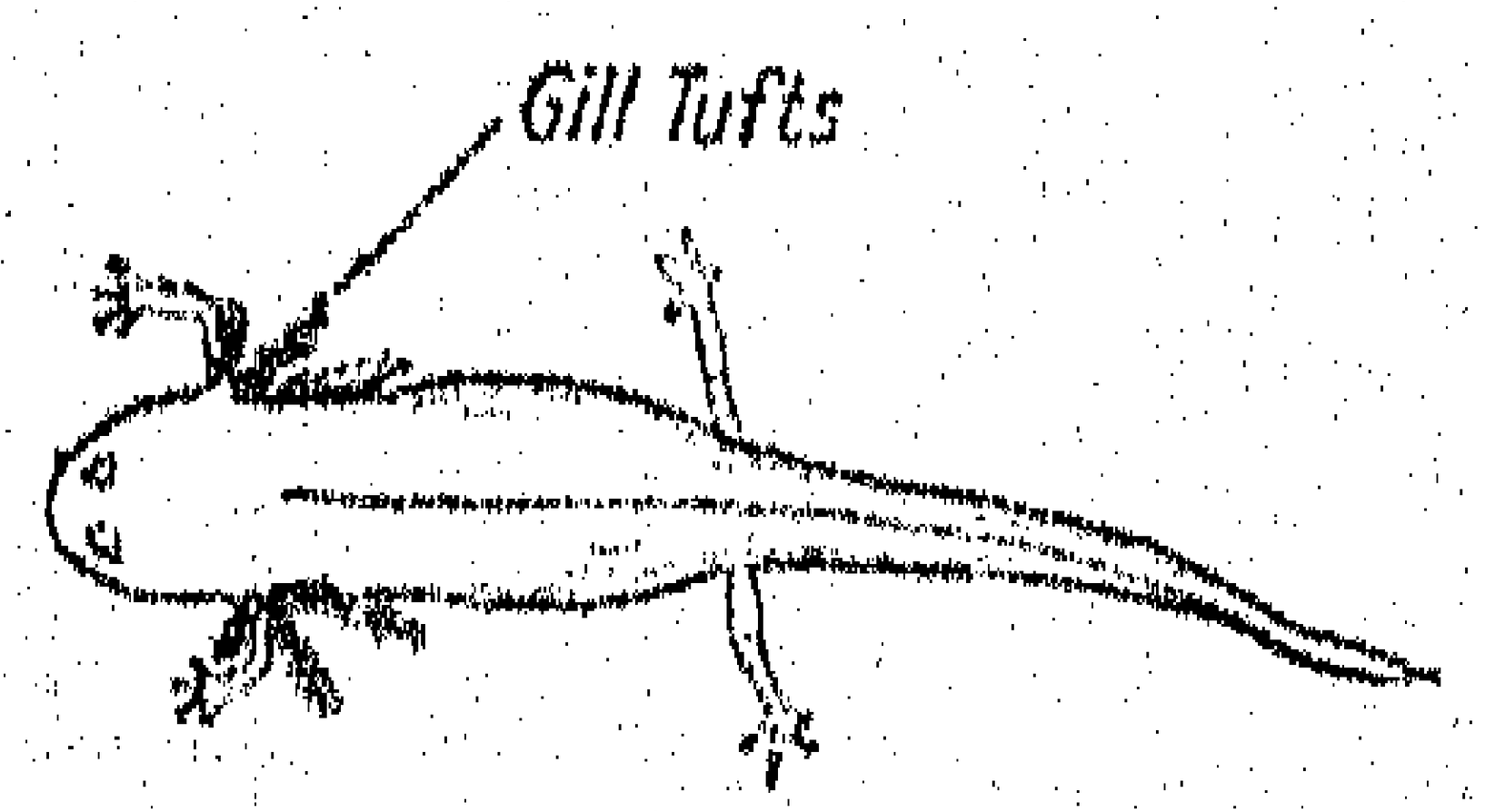


FIG. 39.—Larva of a Common Newt, drawn September 4th (× 1½).

The larva of the Common Newt is spotted with yellow along its sides and tail, and the tail ends in a tiny thread. It feeds on small water creatures and grows in size, becoming less transparent. Soon the front legs appear, and after about two months the back legs also develop. Then the larva looks very like a small sized adult except for the tufts of gills.

Towards autumn the gills disappear and the young newt now has to swim to the surface to gulp in air in order to breathe. In late autumn the young newts leave the water and spend the winter in a quiet state. They do not return to the water until they are ready to breed, which may not be until three or four years later.

KEY TO THE THREE SPECIES OF NEWTS

1	Animal 4 to 6 inches long; skin covered with small warts; crest of male with jagged edge	GREAT CRESTED NEWT
	Animal less than 4 inches long; skin smooth; crest, if present, without a jagged edge	2
2	Tail ending in a short fine thread (very short in females); hind feet distinctly webbed in breeding season; throat very pale pink, without spots; crest of male quite low	PALMATE NEWT
	Tail not ending in a fine thread; hind feet not webbed in breeding season; throat white or yellow with black spots; crest of male with a wavy edge	COMMON NEWT

Newts, together with toads and frogs, make up the class of backboned animals we call AMPHIBIANS (see p. 10). Newts are sometimes mistaken for lizards (which are reptiles). They differ from lizards in having a naked skin without horny scales, in having no horny claws on the toes, and in having the tail flattened from side to side instead of from above to below as it is in lizards. Newts also differ from lizards because they start life as larvæ living in water and breathing through gills, whereas lizards are hatched fully formed from eggs laid on land.

Frogs

Frogs and toads differ in shape from newts, especially in that they lose all trace of a tail when they grow up, but the mode of life of all three is much the same.

Frogs lay their eggs in dense masses called frog spawn, but, before any eggs are laid, the male and female frogs pair up together in the water. The male is carried on the back of the female, holding on tightly with his front paws which are placed across the female's "chest". To enable him to keep his hold in the water (which makes the skin very slippery) the male frog is provided with a swollen patch of roughened skin at the base of each of his thumbs. This "nuptial pad", which is black, provides a good means of distinguishing male from female frogs.

When the female lays her eggs, the male lays sperms on top of them. The sperms swim about in the water until they meet the eggs, and then fertilise them, one sperm to each egg. Many more sperms than eggs are produced, but those sperms that do not find an egg soon die.

Each fertilised egg at once begins to develop into a tadpole. A newly laid egg is black on top and yellowish grey beneath, and is surrounded by a layer of jelly which rapidly swells in the water to form the familiar frog-spawn. The separate eggs forming the spawn cling together because of the jelly and so make it very difficult for water birds and fishes to eat the spawn, for as soon as a duck, for example, fills its beak with the spawn and raises its head to swallow it, the weight of the rest drags the spawn from the beak back into the water.

The larvæ that hatch from frog spawn differ from newt larvæ in having a very smooth body and no legs. These are the familiar tadpoles. The tufts of external gills soon wither away and are replaced by other gills situated on the walls of the tadpole's cheeks. These *opercular* gills are not visible from the outside as they are covered by folds of skin, but on the left side a little spout is to be seen. Through this comes the water which the tadpole has taken in through its mouth and passed over the gills. The hind legs are the first to develop in frog tadpoles, the front pair not appearing until some three months after the tadpole hatches. When the young frog is ready to leave the water the tail gradually shrivels.

In England there are only two species of frog, the Common Grass Frog and the Edible Frog. The Edible Frog is found only at certain places in Norfolk, Bedfordshire, Oxfordshire, Kent, and Cambridgeshire. Edible Frogs can be distinguished from Common Frogs by several features. The Edible Frog is usually greenish in colour and, as a rule, is without the more or less triangular black mark, which in the Common Frog runs back from the eye to behind the ear drum (Fig. 40). Edible Frogs usually have a light yellowish or greenish line running from the snout down the middle of the back to the rump.

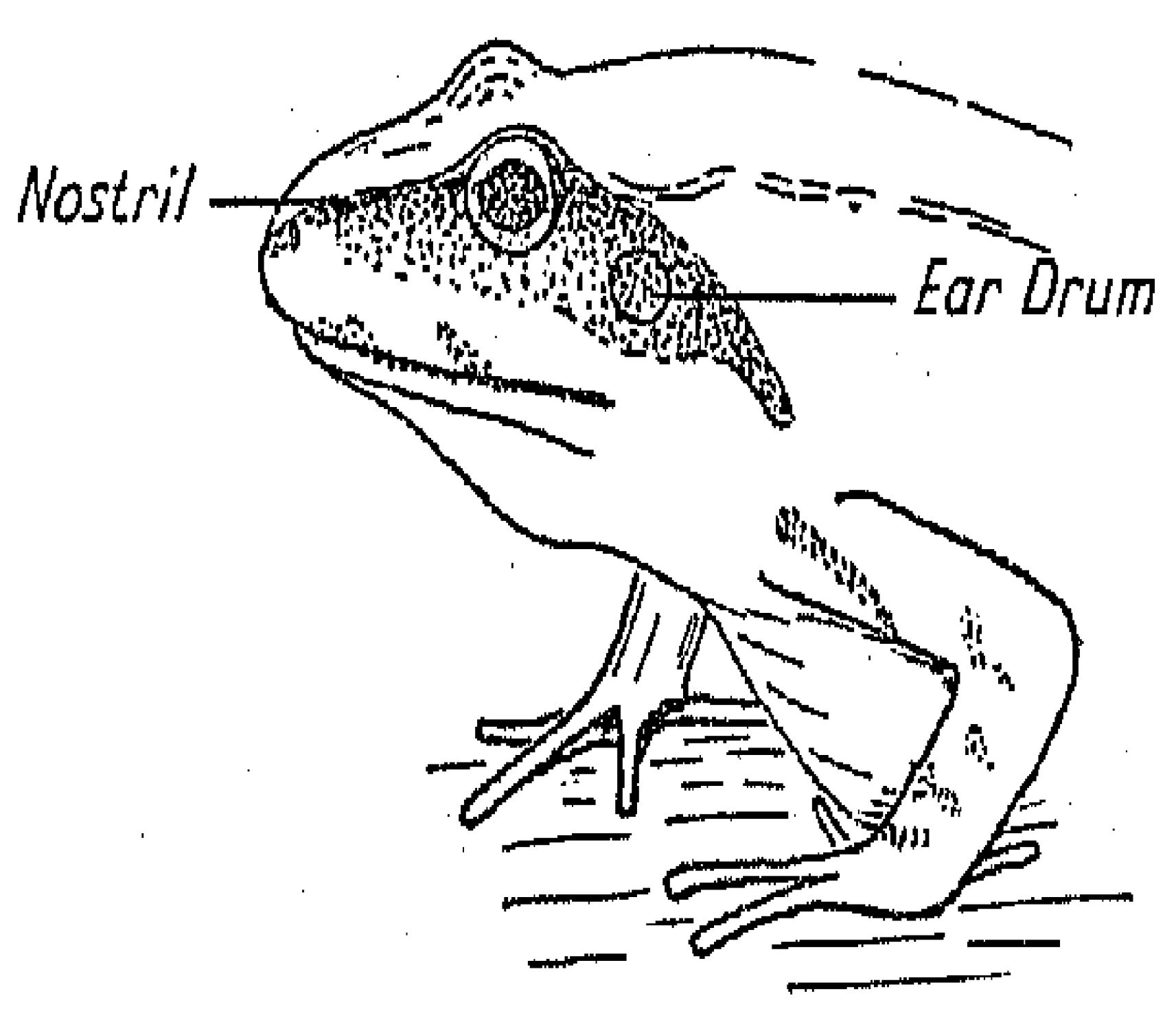


Fig. 40.—Head of Common Frog, to show the oblique dark coloured mark traversing the eye and ear drum. This mark is absent in the Edible Frog.

Toads

Toads differ from frogs in that they are of an altogether heavier build and more clumsy in appearance. The back legs are shorter than those of frogs and the skin is thrown up into very many warts. The warts produce a white liquid which is extremely distasteful to most animals. I once had an Irish terrier dog called Flynn who would attack anything moving. One day, on a walk beside the river, Flynn discovered a toad and immediately seized it, only to drop it a second afterwards with a loud yelp. It was comical to see Flynn violently shaking his head and pawing at his mouth to get rid of the horrid taste. He was still trying to clear his mouth of the offensive matter some minutes later, and though he encountered many other toads, Flynn never picked one up again. The most he would do was to stand a foot or two away and bark furiously.

The eggs of toads are laid in long strings, often 10 feet or more in length. As the string of eggs comes from the body of the female toad, she winds it round the stems of water plants. It is made of jelly-like material and contains a double row of eggs. The eggs hatch into tadpoles very similar to the tadpoles of frogs, and they develop in a like manner.

There are two species of toad found in England, the Common Toad and the smaller Natterjack Toad. The Natterjack is sometimes called the Golden Back Toad because it has a golden band running along its back from the snout to the rump. This band is absent from the Common Toad. The living animals may be distinguished by the way in which they move, for while the Common Toad may move by a series of slow hops or else crawl slowly along, the Natterjack Toad neither hops nor crawls, but runs for a few paces, halts, and then runs on again.

Toads are most useful friends to gardeners. They eat ants, beetles, flies, snails, and various other kinds of small animals. They seem to have a strong "homing" sense and will return to the same retreat over a period of many months. It is also believed that the Common Toad returns to the pond where it was born in order itself to breed in turn. Toads are not poisonous, nor is there any truth in the belief that toads spit at people and blind them. They are quite harmless.

The scientific names of the animals mentioned in this chapter are:—

COMMON NEWT	*Triturus vulgaris*	(try-towr-us vul-gare-is)
GREAT CRESTED NEWT	*Triturus cristatus*	(try-towr-us kris-tart-us)
PALMATE NEWT	*Triturus helveticus*	(try-towr-us hel-vet-ik-us)
COMMON GRASS FROG	*Rana temporaria*	(ra-na tem-po-rare-e-a)
EDIBLE FROG	*Rana esculenta*	(ra-na es-kew-lent-a)
COMMON TOAD	*Bufo bufo*	(bew-fo bew-fo)
NATTERJACK TOAD	*Bufo calamita*	(bew-fo ka-lam-e-ta)

CHAPTER EIGHT

Molluscs

(Snails, slugs, and mussels)

THERE is a phylum of animals whose members are all alike in having a soft body that is not segmented, and in possessing, as a rule, a shell either inside or outside the body. These animals are called MOLLUSCS and they include slugs, snails, oysters, mussels, octopuses and cuttlefishes.

Land Snails

One of the commonest molluscs is the ordinary GARDEN SNAIL *Helix aspersa* (hee-liks ass-pur-sa) (Fig. 42). It carries on the outside of its body a shell, into which it can withdraw if danger threatens or if the weather becomes unsuitable, either too hot and dry, or too cold.

The shell is somewhat globular and is really a tapering tube curled on itself. It is widest at the mouth of the shell (i.e., entrance to the tube), and the spiral gradually narrows down almost to a point. There are from four-and-a-half to five whorls (complete turns) in the shell, but the outer whorl makes up most of its bulk. An average size shell is about 1 inch wide and 1 inch high. The colour varies considerably but usually has a yellowish and purple ground with indications of blackish purple bands (from three to five) running with the spiral. In addition, there is a number of rather dark brown and greenish markings.

The whorls of the shell are rough with ridges running across them. Each ridge was once the edge of the shell, but as the shell was enlarged by the snail during its growth, the new substance was not added quite level with the old, so that these ridges resulted. The shell does not increase at all during the winter and you may be able to make out one or two cross ridges which are altogether stronger than the others and mark the end of one year's growth.

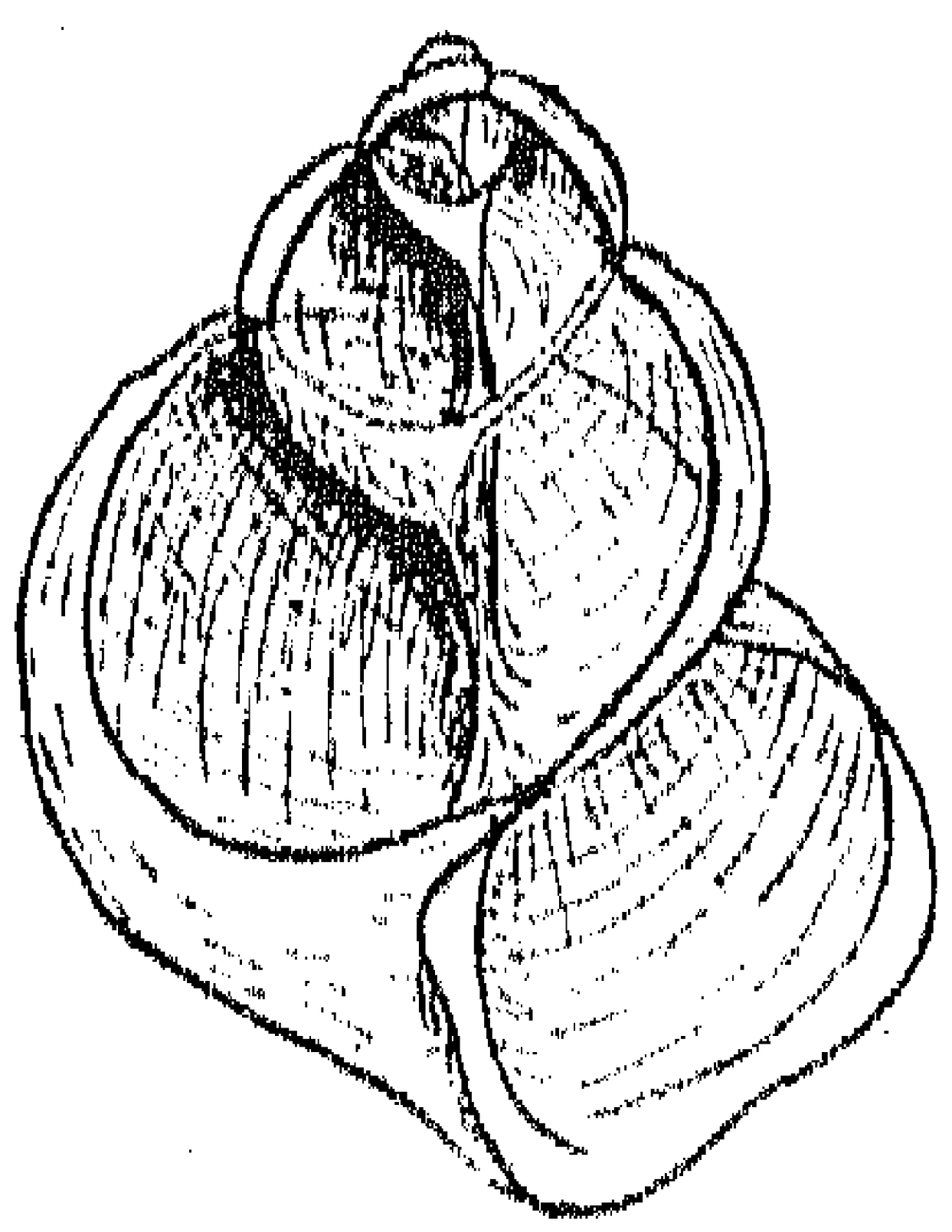


FIG. 41.—Shell of Garden Snail with part cut away to display the internal structure, ×1¼.

If you obtain an empty shell and cut away the front part with scissors (Fig. 41) you will be able to see the internal structure. Where the whorls touch in the centre, a kind of pillar is formed. This is called the columella.

When a snail is crawling along, several parts of its body are visible. The part in contact with the ground is called the foot, and the sole of the foot is a creamy white. Persuade a snail to crawl over a piece of glass and observe its foot from the underside as it crawls. You will see alternating dark and light bands start from the hind end and move steadily forward to disappear at the front end. These are the result of the snail's method of gliding. The slime which a snail gives out makes the surface of the ground suitable for its gliding movements, so we may say that the snail lays down its own track as it goes along.

While looking at the underside of a snail as it crawls upon a piece of glass, you will be able to see near the front end, the mouth bordered by two fleshy flaps. The mouth is not open all the time, but now and then it does open and will enable you to see the brown top jaw. This is a horny bar with a number of ridges on it. The bar is supported by a triangular piece of material (Fig. 42*f*). You can easily remove the top jaw from a snail with a needle and razor scalpel (p. 6) if you first kill the snail by drowning it. To do this, leave the snail in a tin of warm water overnight. It will slowly and painlessly die from lack of oxygen, and furthermore will come out of its shell to do so.

At the front end of the animal are four tentacles, a pair of longer ones arising from the top of the head and a much smaller pair situated lower down and somewhat further in front (Fig. 42, *c–d*). The tentacles are sense organs and respond at once to being touched or to the presence of irritating substances, such as tobacco smoke. The tentacles can be withdrawn inside the snail's body. This is made possible because the tentacles are hollow so that, when they are withdrawn, their tips are pulled down inside the walls in much the same way as the finger of a glove can be pulled down from inside the glove. The quickest way to understand this is to watch a live snail either with the naked eye or through a hand lens. Each of the larger tentacles has a jet black eye at its tip when the tentacle is fully expanded, but at the first sign of danger the eye is drawn down inside the centre of the tentacle. You can easily observe this.

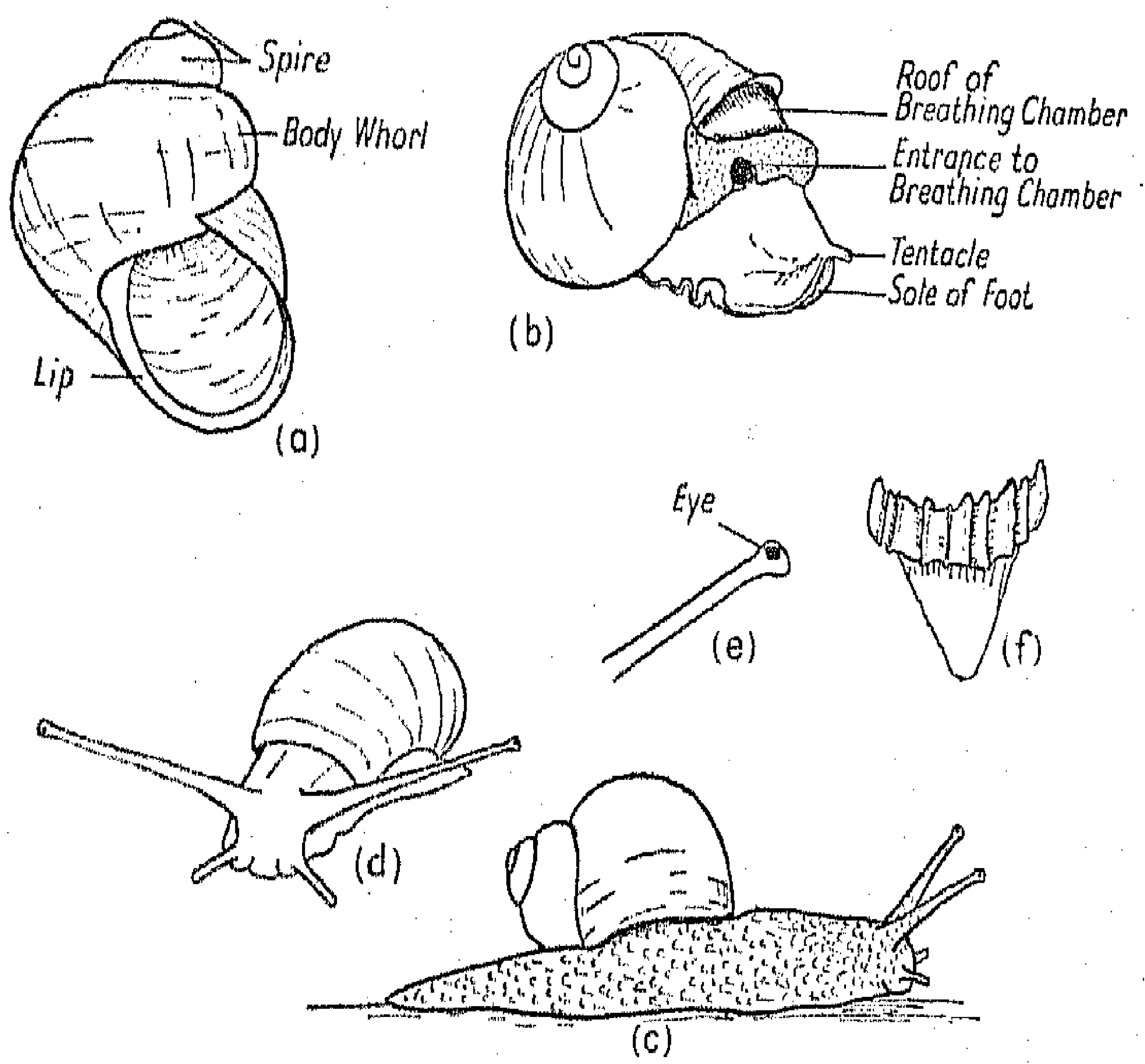


FIG. 42.—(*a*) shell of Garden Snail, *Helix aspersa*; (*b*) Garden Snail, killed by drowning in warm water; (*c*) live specimen from the side; (*d*) the same from in front; (*e*) a tentacle drawn to show the eye at the tip; (*f*) the jaw. (*a*), (*b*), (*c*), (*d*) somewhat reduced, (*e*) ×2, (*f*) ×5.

The upper parts of the body are covered with smoky grey coloured skin which is itself covered with rather coarse wart-like projections, a little lighter in colour than the rest of the skin. More or less closing the entrance to the shell is a greenish yellow flap of tissue called the mantle. On the right hand side this has a circular hole through which air enters into the breathing chamber situated in the first whorl of the shell. To get a clearer view of the mantle, breathing hole, and breathing chamber, it is best to kill a snail by drowning it as described above.

Garden snails are most active at night. During the day they hide under large stones, in the corners of walls, or in holes in the ground. They do sometimes come out in the early evening after rainstorms. Many garden snails return to the same spot to hide day after day. This homing behaviour is shown by other molluscs and has been especially studied in the limpets which you may find clinging to rocks along the seashore. Limpets return to the identical spot after each journey in search of food, and their shells grow in such a manner that they fit exactly into the irregularities of the rocks. It is probably important to a limpet that it should fit flush on to a rock in this manner, because then it will be better able to resist the force of the waves tending to dislodge it. As no two places on a rock's surface are alike, the value of the limpet's returning always to the same spot is clear.

The Garden Snail lays several batches of eggs during the summer months. Each egg is a transparent ball about $\frac{1}{8}$ inch in diameter. There are between 40 and 100 in a batch and they are laid under loose soil in holes dug by the snails. They hatch in about 30 days. If you are lucky enough to find some snail's eggs when you are digging the garden, you can easily hatch them by putting them in a box with some soil and laying a piece of turf on top, or by putting some of the eggs into a jam-pot with some moist—not wet—soil.

During the winter the Garden Snail hibernates. It finds some sheltered spot, e.g., a wall covered with ivy or some other creeper, the corner of a shed, or a hole in a rockery, and then retreats into its shell to pass into a torpid state. The mouth of the shell is closed by a tough membrane or sheet made by the foot and called the *epiphragm*.

During very dry weather in summer, the snail may have a similar period of quiet during which it withdraws into its shell and forms an epiphragm, though the summer epiphragms are never so thick as the winter ones. If you place a few snails in a dry jam-pot or box and cover them, they are almost certain to make these summer epiphragms within a few days.

Water Snails

There are many other land snails, but these do not differ greatly from the common snail except in the shape of the shell. However, a considerable number of snails inhabit fresh water and these do show certain differences from the typical land snails. A number of them carry a more or less oval plate of horny material on the hind end of the foot. This plate is called the *operculum* and it is used to close the mouth of the shell when the snail has withdrawn inside (Fig. 43). The snails provided with an operculum belong to the group we call the OPERCULATE SNAILS. By means of special gills they breathe the oxygen dissolved in the water, and so do not have to come to the surface to breathe. In still water, such as ponds and canals, there tends to be not much oxygen, hence these snails are usually found in running water.

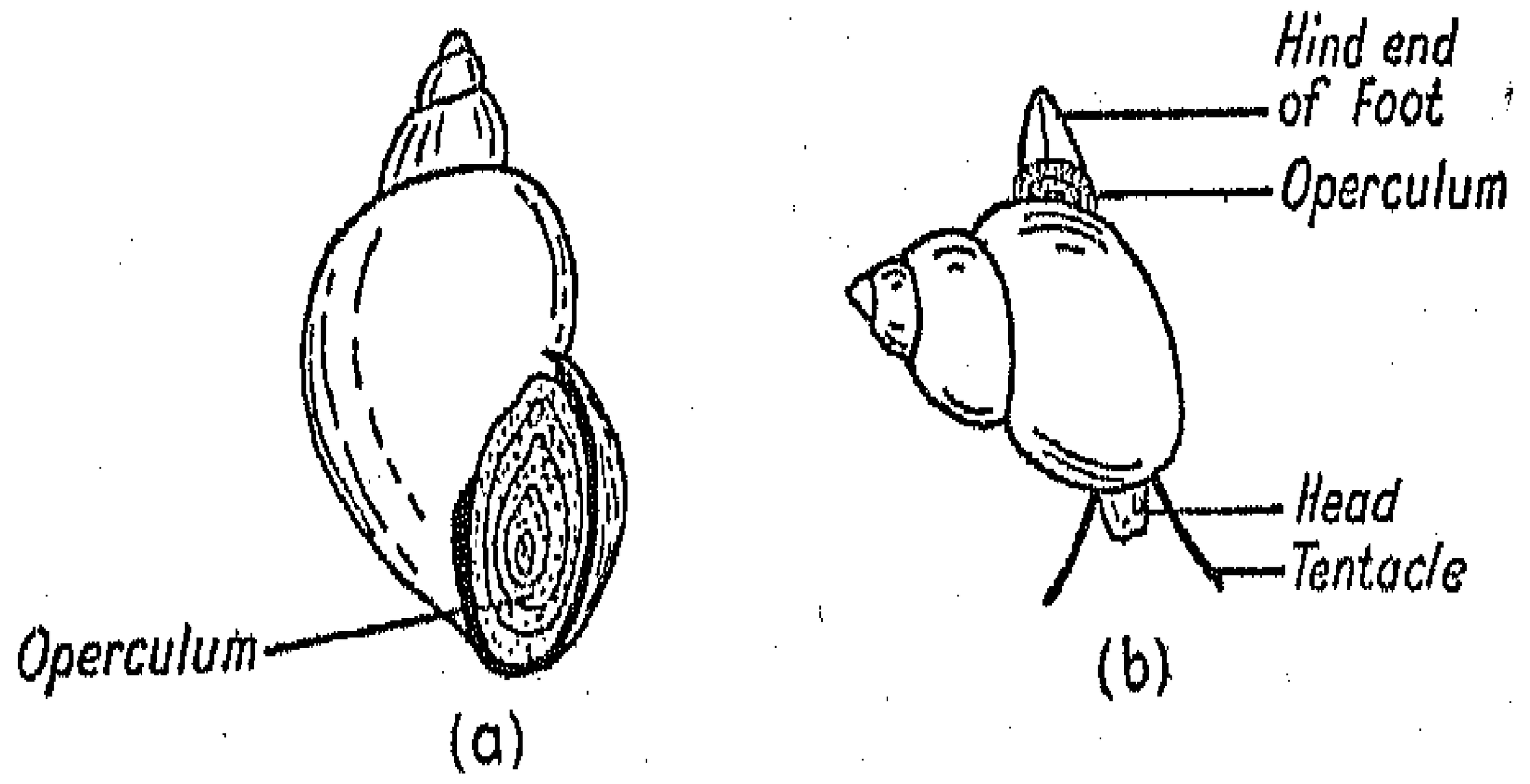


FIG. 43.—An operculate snail, *Bithynia tentaculata.* (*a*) animal withdrawn inside the shell, which is closed by the operculum, ×2½; (*b*) an active specimen, drawn from above, ×2.

Other freshwater snails have neither operculum nor gills and come to the surface to obtain oxygen from the air, although they are able to breathe through their skin some of the oxygen dissolved in the water. Members of this group are most often found in still water, and some are very abundant.

One of the commonest is the COMMON POND SNAIL, *Limnæa stagnalis* (lim-nee-a stag-nay-lis), a picture of which is given in Fig. 44. There are several points of difference between it and the Common Snail (*Helix aspersa*). The shell is much thinner—indeed, all freshwater snails have thin shells—and is drawn out into a pronounced spire, which is quite sharply pointed. When the animal

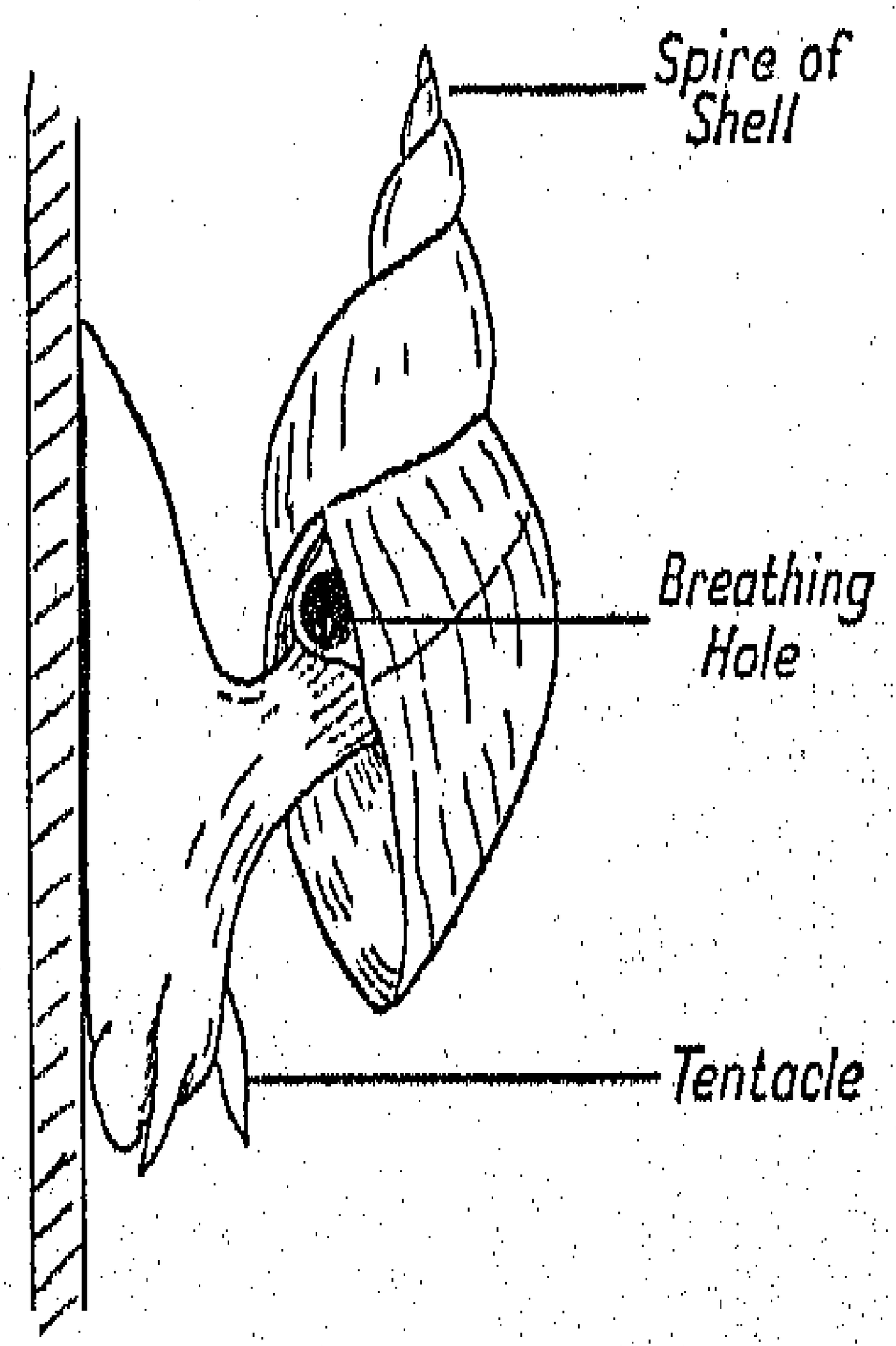


FIG. 44.—Common Pond Snail (*Limnæa stagnalis*) drawn while it was breathing at the surface. The snail adhered to the side of the aquarium while it applied its breathing aperture to the surface of the water. Note the single pair of flat, triangular tentacles, ×1.

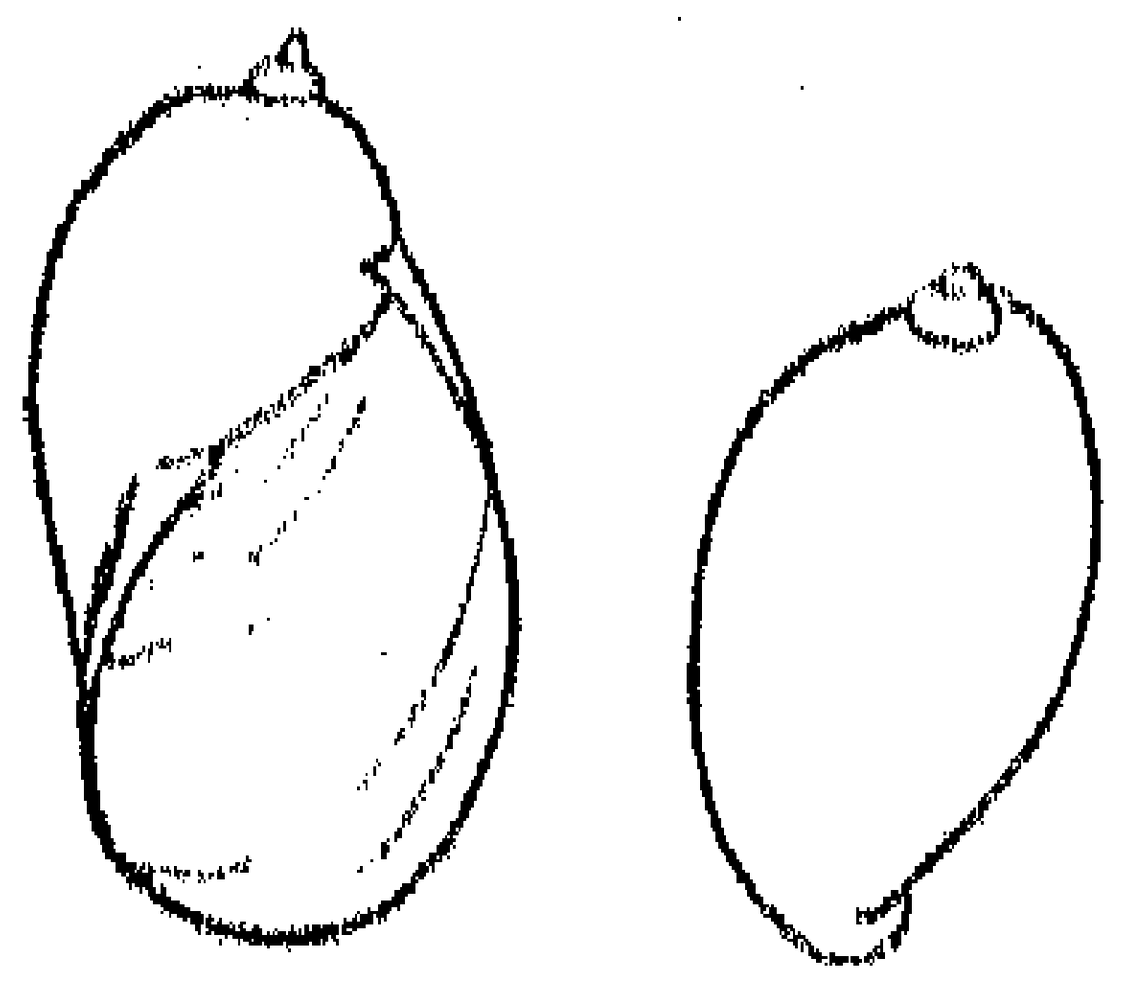


FIG. 45. — Shell of Wandering Snail, *Limnæa peregrer*, ×2.

is out of its shell, you will observe that it has only two tentacles. These are rather flat and triangular in shape and cannot be withdrawn as can the tentacles of land snails. Furthermore, they have no eyes at their tips. In all water snails, the eyes are situated at the bases of the tentacles.

The Common Pond Snail is a most suitable animal to keep in an aquarium. It will crawl about the walls and across the surface film of the water. The walls of aquaria usually develop a growth of tiny water plants, *algæ* (al-je), and you will be able to see the snail rasping this off with its tongue. You should watch the action of the tongue through a hand lens.

At intervals, a Pond Snail will give off a cylindrical coil of waste matter (the droppings or *fæces*) which is about as thick as the lead in a pencil. If you have many snails in an aquarium, the sand on the floor will soon become covered with these droppings.

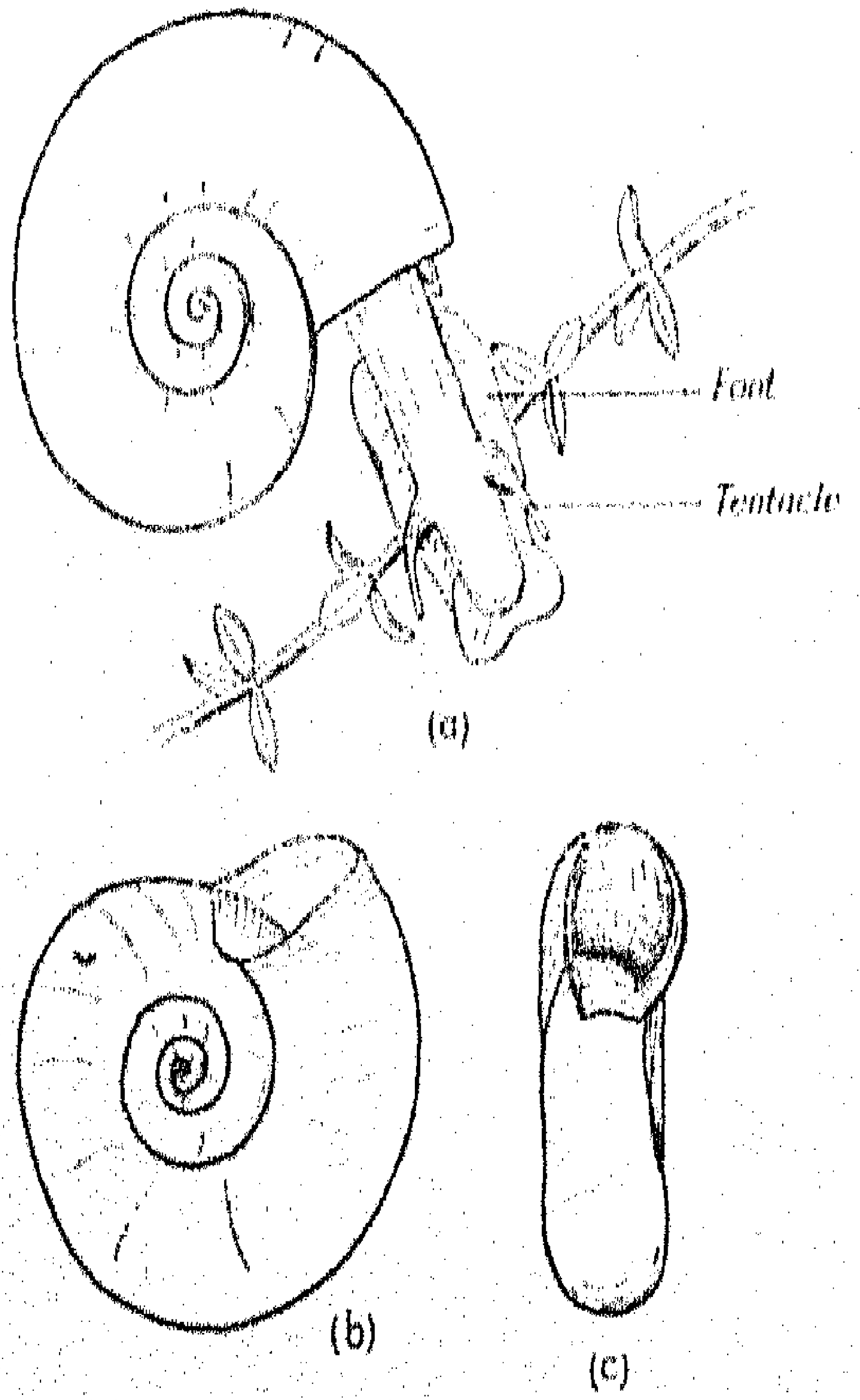


FIG. 46.—(*a*) Ram's Horn Snail, feeding; (*b*) and (*c*) two views of the shell. All natural size.

Perhaps the commonest snail of all in still water is the WANDERING SNAIL, *Limnæa peregrer* (lim-nee-a per-re-grer). This is not as large as the Pond Snail, and the last whorl of the shell is much more swollen in comparison with the others. A drawing is given in Fig. 45, but the shape of the shell is rather variable.

There is a genus of snails called the TRUMPET SNAILS, genus *Planorbis* (plan-nawrb-is), in which the coils of the shell are not drawn out into a spiral but instead make a flat spiral like a coiled watch spring (Fig. 46). Members of this genus are quite common.

Water snails frequently lay their eggs on the walls of aquaria. The eggs are embedded in a mass of stiff transparent jelly, and, if left, will soon hatch into tiny snails. In most species of snail there are not separate males and females. Each snail makes both eggs and sperms, but the eggs of any one particular snail are fertilised by sperms from another snail.

Slugs

Slugs are a group of molluscs in which the shell has either disappeared altogether or become very small and invisible from the outside of the animal. There are four genera of British slugs with several common species, but I will describe in detail only the COMMON BLACK SLUG, *Arion ater* (ar-ri-on at-ter). The name Black Slug is not really suitable because there are very many colour varieties of this slug, particularly forms that are mainly chocolate or yellowish brown. However, it is fairly easy to recognise *Arion ater* from its shape, and the black variety is the most common.

When it is fully grown, the slug may reach a length of 8 inches, but specimens about 4 inches are more common. When it is moving, it has the form shown in Fig. 47 *a–b*.

The body is long and rather fat, and where it meets the foot it is expanded into a foot fringe marked by transverse dark lines. There are four tentacles at the front of the head, a longer pair on top and a shorter pair beneath them. The top pair have eyes at their tips. The top region of the head, in between the bases of the larger pair of tentacles, is marked with four distinct furrows (Fig. 47*d*). Just behind the head, the mantle lies over the body in the form of an oval shield. Its surface is prominently marked with little pimples. On its right side and towards the front, the edge of the mantle is deeply notched. The hole which this notch surrounds leads into the breathing chamber. The edges of the mantle are free from the body at the front and can be lifted with a needle or matchstick. At the hind end, the mantle edges are attached to the body.

The skin over the rest of the body, apart from the mantle, is covered with rather coarse wrinkles arranged in about three dozen rows. The ridges are broken by much finer cross furrows.

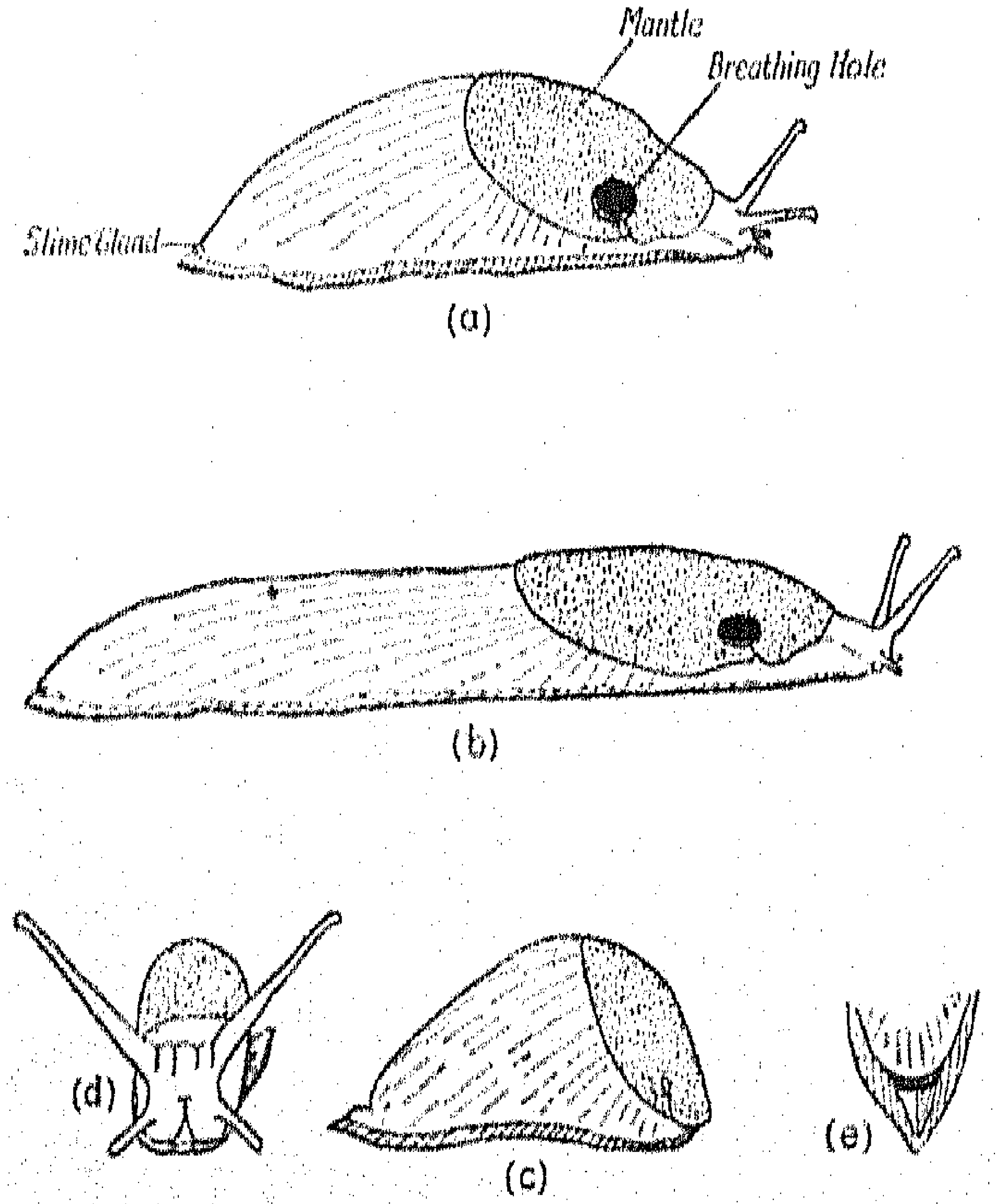


FIG. 47.—The Common Black Slug, *Arion ater.* (*a*) and (*b*) two views from the right side; (*c*) shows the characteristic attitude adopted by this snail when it is irritated; (*d*) view from the front to show the four furrows on the forehead; (*e*) enlarged view of the tip of the tail seen from above, to show the slime gland. All, except (*e*), somewhat reduced.

Just above the tip of the tail is a prominent V-shaped slit. This is the opening of the slime gland and sometimes, in a live slug, you will see a mass of stiff jelly-like slime given off from here. It is said that, before two of these slugs mate, one comes up behind the other and begins to eat the slime given off from the tail gland. Soon the first slug finds the slime trail from the second and begins to eat that, so, for a short while, each slug is eating the slime from the other one. After that, pairing takes place, so we must regard this curious behaviour as a kind of courtship. I have not seen it myself but I have seen one of these slugs eat the slime from its own gland.

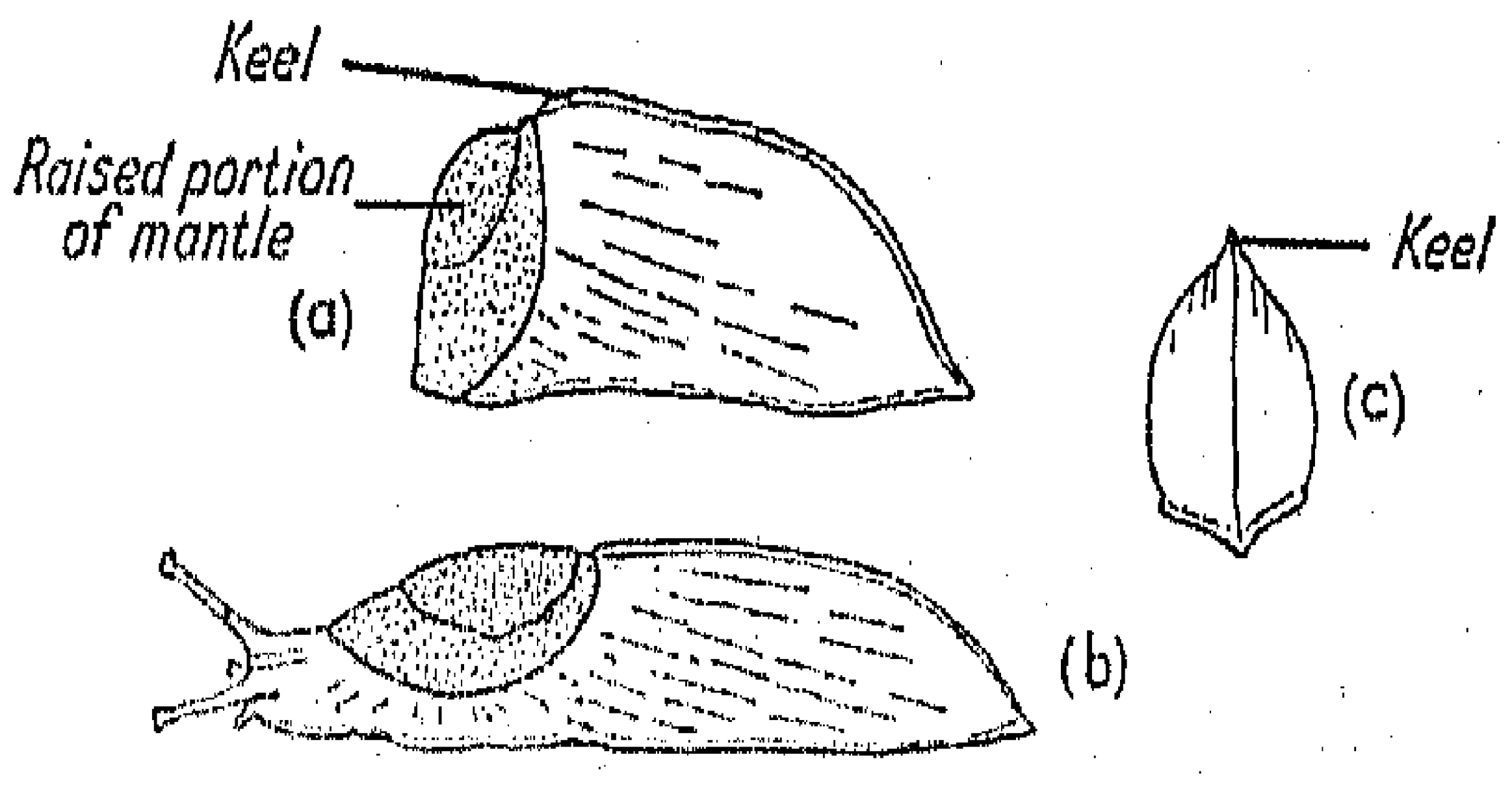


FIG. 48.—The Keeled Slug, *Milax sowerbyi.* (*a*) with head withdrawn under the mantle; (*b*) active specimen; (*c*) rear view, showing the keel. All ×1.

When the Black Slug is touched it hunches up its body in a very characteristic way (Fig. 47*c*), and sways slowly from side to side, though to make a slug do this you may have to prod it repeatedly. No other species of British slug has this habit. The Black Slug passes the winter in a hole in the ground.

In their general features other British slugs are much the same as the Black Slug. Some have a sharp ridge or keel running down the back (Fig. 48), while in others the slime gland over the tail is absent. The Black Slug itself has no shell, but some other slugs do have shells. When present, the shell is concealed inside the mantle, but may easily be dissected from a dead animal. These shells are discs of limy material more or less oval in shape. In some genera of slugs the breathing opening is placed near the hind end of the mantle instead of near the front end.

The following key should enable you to find the genus to which any particular slug you may obtain belongs.

KEY TO GENERA OF BRITISH SLUGS

1	A mucus gland present over the tail; the breathing hole placed in the front half of the mantle	*Arion*
	No mucus gland present over the tail; the breathing hole placed in the hind half of the mantle	2
2	The back possessing a sharp ridge or keel along its entire length; the mantle covered with fine granules	KEELED SLUGS (*Milax*)
	The back not sharply keeled—at most only a blunt ridge at the hind end; the mantle marked with concentric rings of wrinkles	3
3	The body with at least traces of dark bands (1 or more) running down the sides*	*Limax*
	Body with no trace of dark bands running along the sides	4
4	Shield spotted with yellow—body slime yellow	YELLOW SLUG (*Limax flavus*)
	Shield not spotted with yellow; slime not yellow—either white or clear	*Agriolimax*

* Occasional adult specimens may be met with that have lost all traces of their dark bands.

Mussels

Slugs and snails have a shell which is all in one piece. Because of this they are called *uni-valves*. The members of another group of molluscs have their shells made of two pieces which are hinged together like the two flaps of a cigarette case. These molluscs are called *bi-valves*, and they include oysters, mussels, cockles, clams, razorshells, and many other forms.

All bi-valve molluscs live in water, usually in the sea, but there are some British freshwater forms. The largest is the Swan Mussel which is commonly present in lakes, canals, ponds, and slow streams.

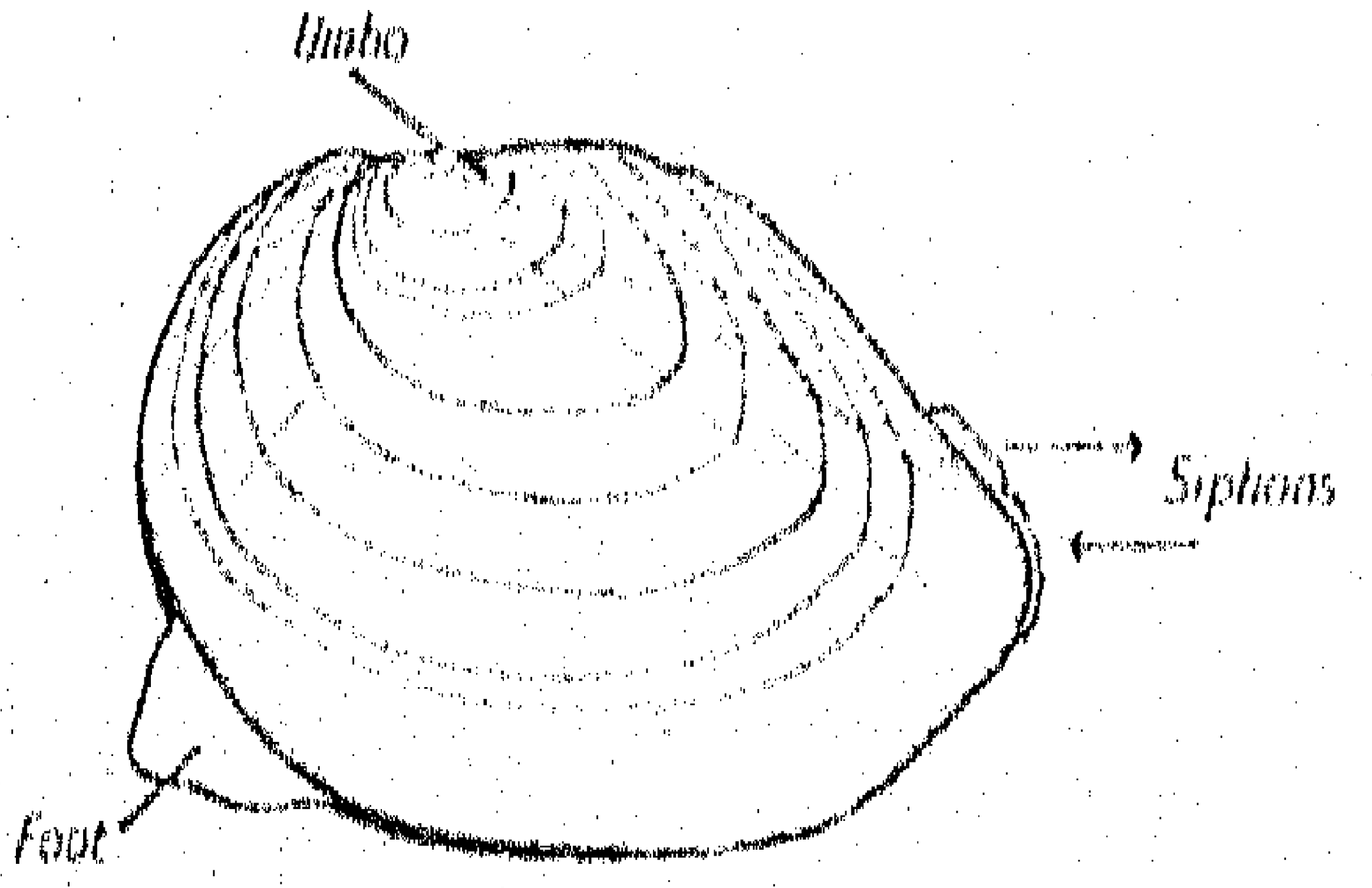


Fig. 49.—Fresh Water Mussel; live specimen lying on sand (× ½).

An external view of the animal is given in Fig. 49. There is little to be seen except the large valves (or pieces) of the shell. The *umbones* (singular *umbo*) are two prominent swellings, one on each valve of the shell near to the hinged edge. The umbones represent the youngest parts of the shell to which more material has been added as the animal has grown in size, and lines of growth are as clearly visible as they were in the shell of the snail. The two valves of the shell are hinged together along the flat edges near the umbones and are held together by strong muscles attached to the inside surfaces.

If you study a live Swan Mussel in an aquarium or a bowl of water, you will see a fleshy yellow projection pushing out from between the two valves of the shell. This is the foot of the animal and it corresponds to the foot of the snail. By making muscular movements, it can move slowly through mud on the bottom of a pond, carrying the shell with it. It leaves a distinct furrow and in canals or ponds where the water is clear these furrows are very obvious, extending often for 18 inches with the Mussel at one end, more or less buried in the mud.

In the live animal, when it is undisturbed in water, you can see two slit-like holes at the end of the shell opposite to the foot. There is a small oval one at the top surrounded by a fleshy lip, and below this another, more slit like, also surrounded by a fleshy lip which here, however, is drawn out into a fringe of finger-like tentacles. These slits are called the siphons. Through the larger one a current of water is passing into the animal, while through the smaller a water current is passing out. The water currents will be made visible if you add a *small amount* of mud to the water. The smaller hole is called the exhalent siphon because it gives out water, and the other is called the inhalent siphon.

To see more of the structure of the Swan Mussel, you will have to remove one of the valves of the shell. As soon as you pick up a live Mussel, the foot and the lips of the siphon will be withdrawn into the shell and the two valves pulled tightly together. As the edges of the shell are soft, they make a good fit. If the Mussel is kept cool, it can live out of water in this condition for a day or more, because it retains inside its shell sufficient moisture to enable it to keep alive.

Although the two parts seem so tightly closed together, it is not difficult to remove half of the shell. The muscles holding the valves together can withstand quite a considerable force for brief periods, but they seem incapable of withstanding a much smaller force applied for a longer time. Push a ruler in between the valves and twist it slowly so as to prise the shell partly open. Do this steadily and without haste and you will find the shell gradually yield. When it has opened a little way, wedge it with a pencil and remove the ruler.

Now you should be able to see a fleshy sheet of tissue (the mantle) lining the shell. Work the blade of a sharp penknife between this and the shell and feel for the muscle that is holding the shell. Look at Fig. 50 to see where the muscles are. When you can feel the muscles at one end, cut through them. Then do the same for the muscles at the other end. The shell will now turn back quite easily and the body of the Swan Mussel will be visible.

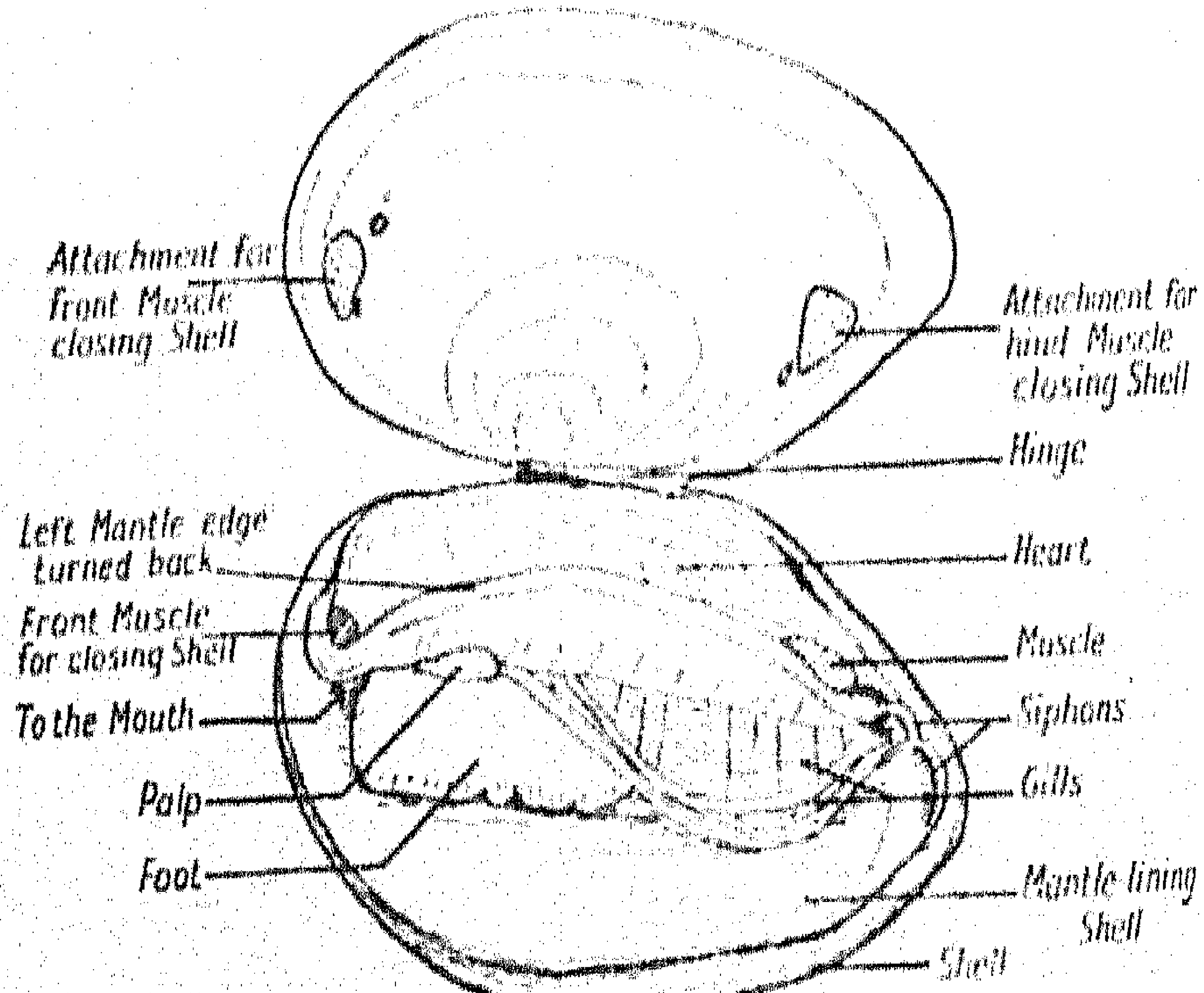
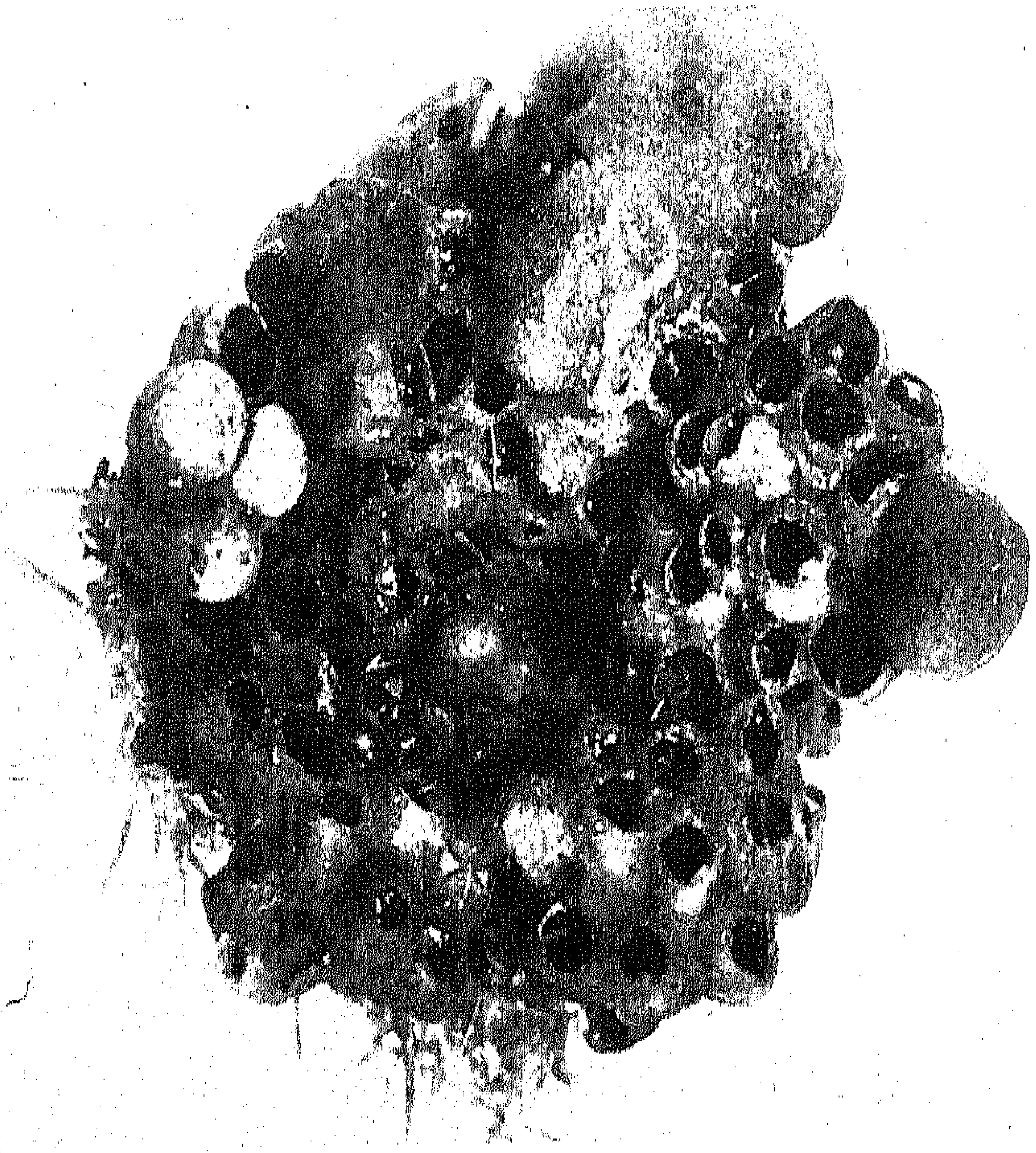
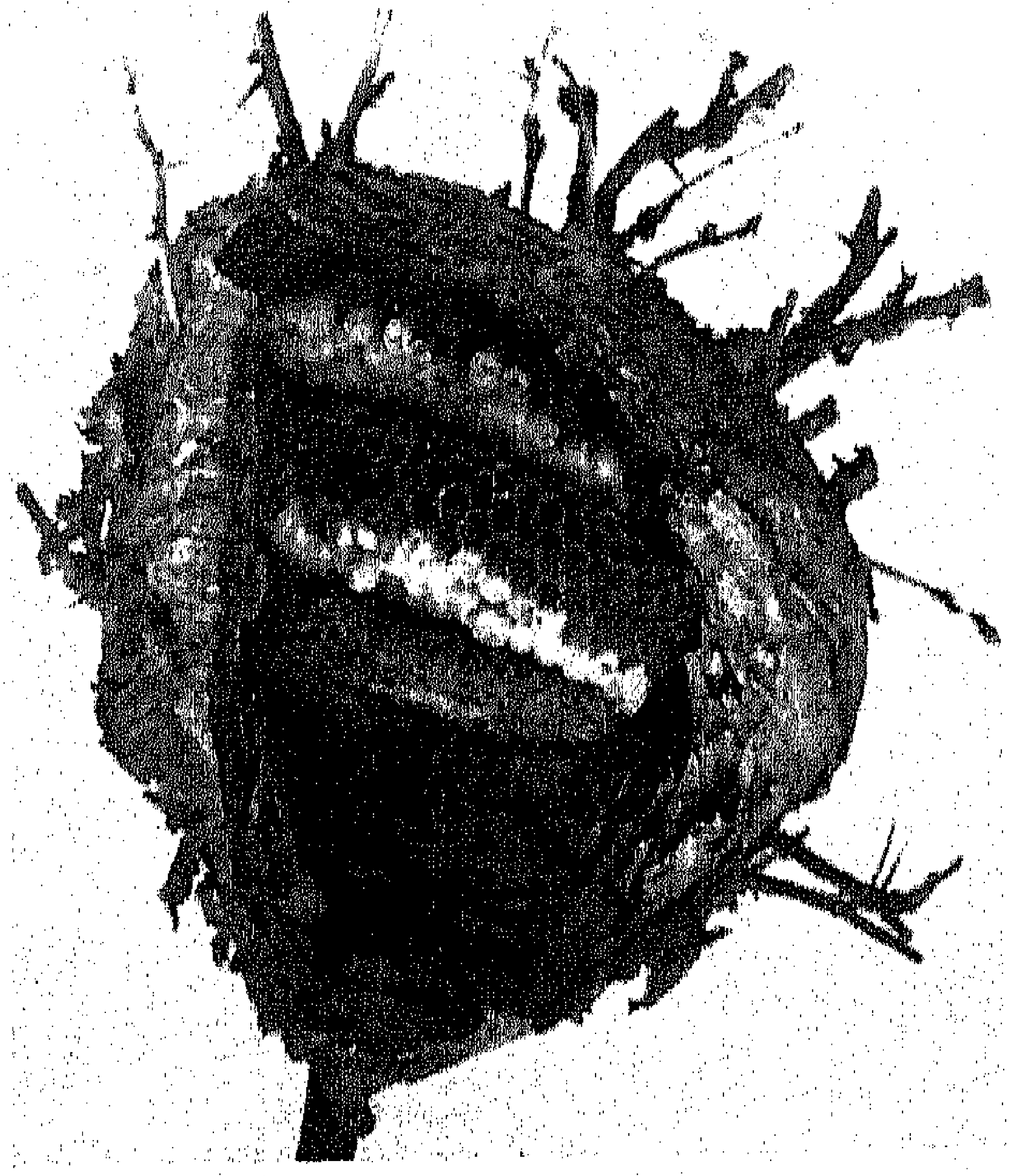

Attachment for front Muscle closing Shell
Attachment for hind Muscle closing Shell
Hinge
Left Mantle edge turned back
Heart
Front Muscle for closing Shell
Muscle
To the Mouth
Siphons
Palp
Gills
Foot
Mantle lining Shell
Shell

Fig. 50.—Fresh Water Mussel, with the muscles to the left valve cut, and the valve raised so as to display the animal (× ⅔).

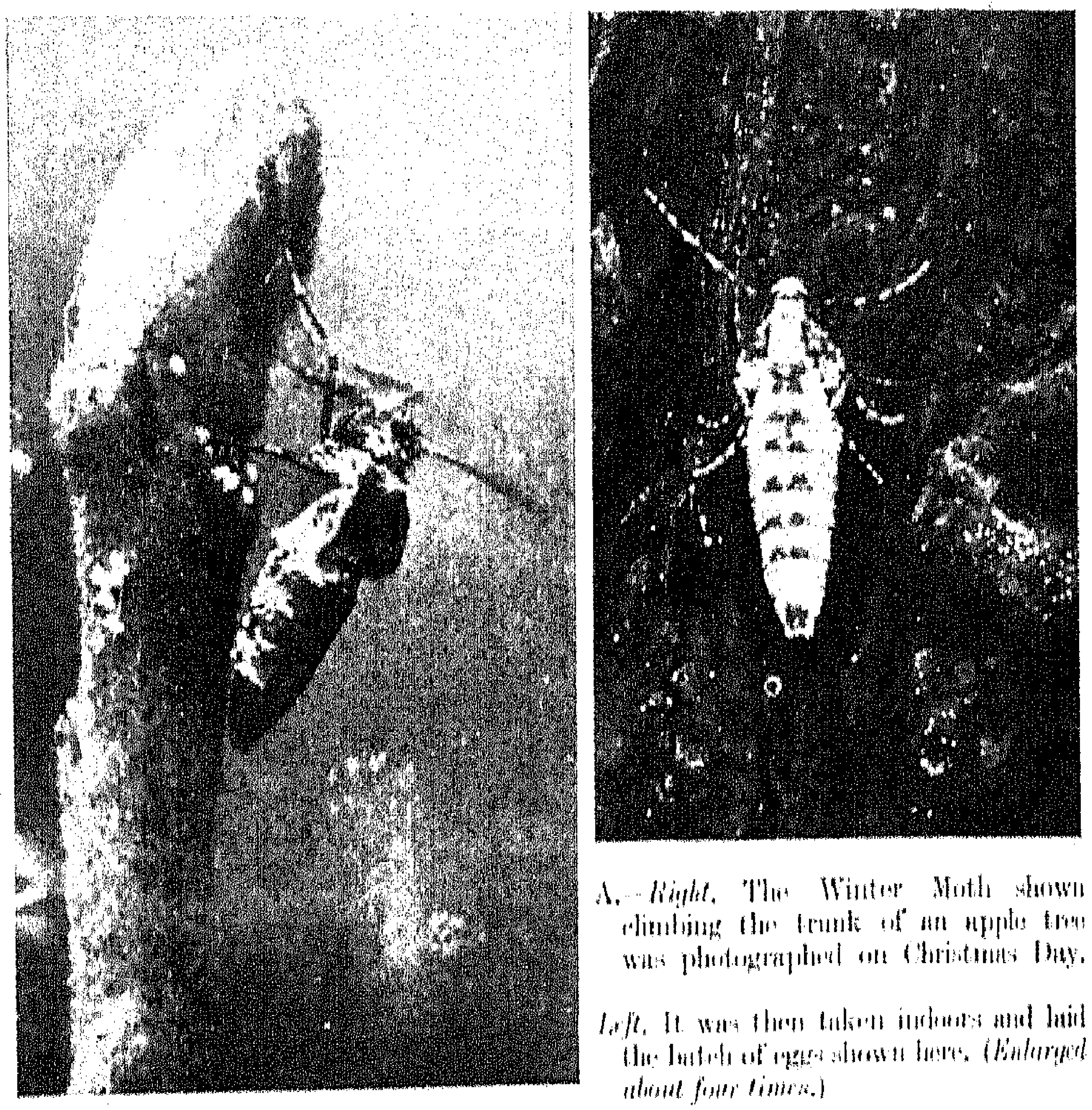


A. Nest of a Moss Carder Bee, taken in August and photographed from above. The smooth lumps at the top contain worker brood, while the large whitish cells on the right contain queen larvae. Nectar is visible in some of the other cells. (*Somewhat enlarged.*)



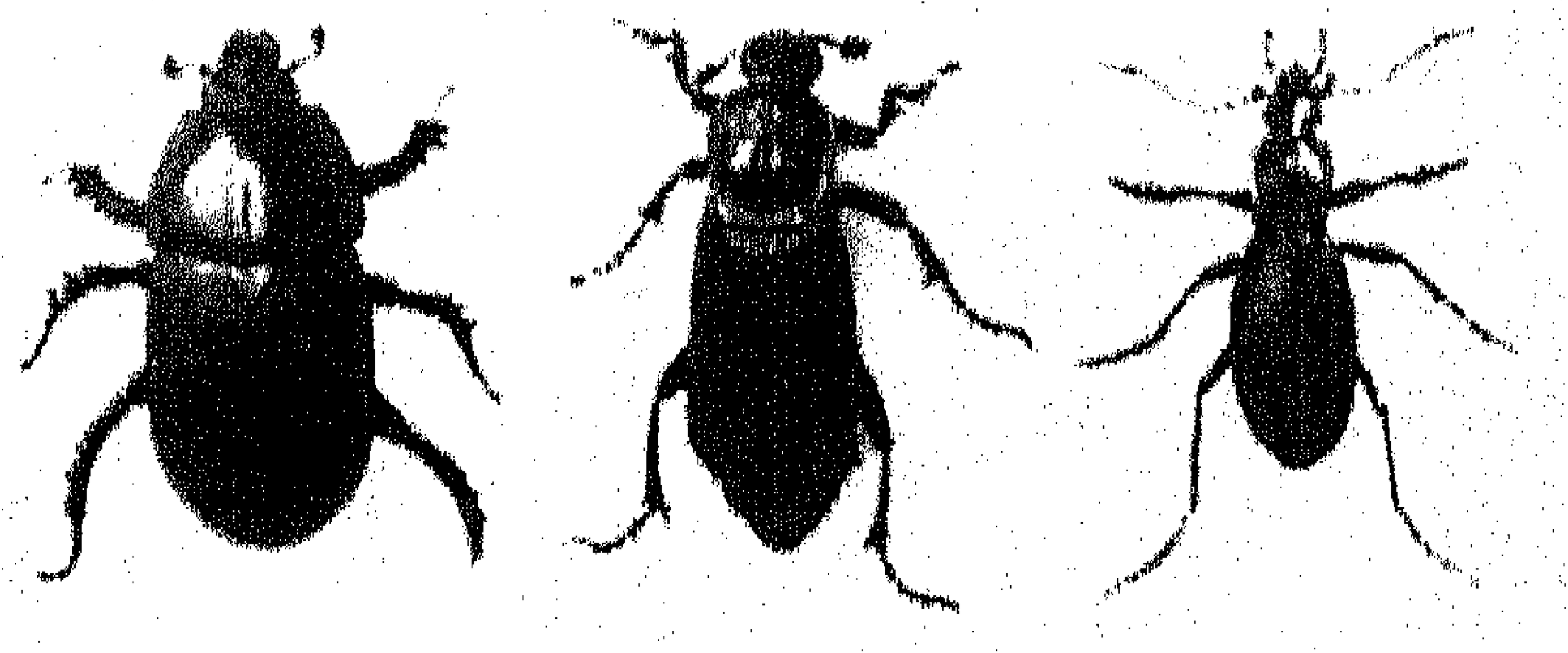
B. Nest of a Norwegian Wasp, built in a gooseberry bush. A part of the wall of the nest has been cut away to disclose the plates of comb suspended from the roof. (*Reduced.*)

PLATE IV



A.—*Right.* The Winter Moth shown climbing the trunk of an apple tree was photographed on Christmas Day.

Left. It was then taken indoors and laid the batch of eggs shown here. (*Enlarged about four times.*)



B.— Dung Beetle (*Geotrupes stercorarius*) Sexton Beetle (*Necrophorus humator*) Violet Ground Beetle (*Carabus violaceus*)

(*All enlarged.*)

The mantle flap which you have separated from the shell will be on top, and sticking through it will be the white stumps of the muscles. Underneath the mantle is the yellow foot and the very prominent gills filling up most of the shell. There are two pairs of gills, and each gill is made up of very many fine threads which are joined to one another in numerous places to make a close-meshed sieve. The mouth is not easy to see. It lies at the top of the foot in the position shown in Fig. 50 and it has two fleshy flaps called palps on each side of it. At the other end of the body, opposite to the exhalent siphon, is the anus through which waste material is passed to be removed in the stream of water going out through the exhalent siphon. The heart is also visible, through a patch of transparent skin (Fig. 50).

The Mussel feeds on tiny living things brought by the water current entering through the inhalent siphon. These small particles are filtered off by the gills, entangled in slime, and passed along to the mouth. This is possible because the gills and some other parts are covered with tiny hairs called *cilia* which keep up a constant lashing movement that is particularly strong in one direction, so that particles on them are slowly carried along. If you have ever been in a crowd where someone has fainted and has been passed back over the heads of the people to the outside by many helping hands you will have a reasonable picture of what goes on. The little hairs correspond to the hands of the people in the crowd, held above their heads, to help pass the unconscious person along. In this way, the food, entangled in slime, gets passed along to the mouth.

A Swan Mussel is either a male or a female. In the females the young larvæ are kept in the outer pairs of gills, which become much swollen. About February the larvæ are passed from here into the water, but they cannot grow at once into adult Swan Mussels. They have to spend a period of some months attached to the skin of a fish, in order to develop properly. If they cannot get on to a fish's skin they die, and very many must perish for this reason. However, each year a female Mussel will lay about half a million eggs and, in order to maintain the number of Mussels in a given stretch of water, it is necessary for only one of these to reach maturity to replace each adult male or female that dies.

The reason why the shells of dead bivalves gape open is that the hinge is rather elastic, so that once the pull of the muscles no longer operates to close the valves, they spring open.

Very similar to the Swan Mussel, *Anodonta cygnea* (an-o-don-ta sig-ne-a), are the members of another genus *Unio* (yu-ne-o). They are about the same size, but may be distinguished from *Anodonta* by the presence of a sunken area between the umbones and the blunt end of the shell (Fig. 51). *Unio* occurs in the same places as *Anodonta.*

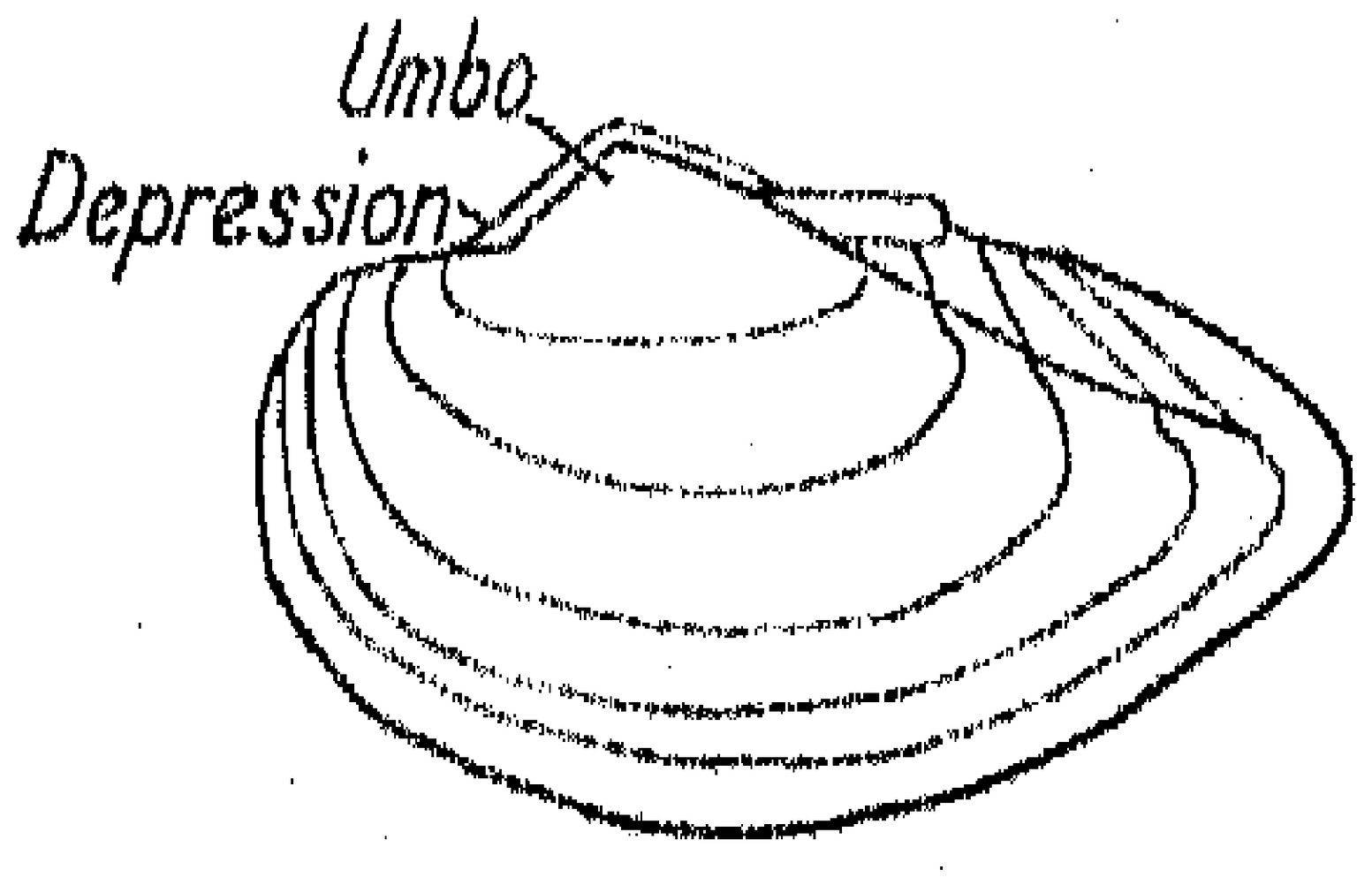


FIG. 51.—Fresh Water Mussel, *Unio.*

Very much smaller than *Anodonta* and *Unio* are the ORB SHELLS, genus *Sphærium* (sfeer-e-um). These bivalves are only about ½ inch long when fully grown. The shell is whitish and the valves bulge outwards much more than in *Anodonta* and *Unio.* Each umbo is practically in the middle of the hinge surface. Fig. 52 gives its usual appearance. There are four species, but all are very similar.

Even smaller than the Orb Shells are the PEA SHELLS, genus *Pisidium* (pi-sid-e-um). They are only about ⅛ inch long. Though very like small Orb Shells, the live animals can easily be distinguished, for whereas Orb Shells have two siphons, Pea Shells have but one. There are a number of species, but all are very similar, and some occur in practically every stretch of permanent water. If you scoop mud from the bottom and examine it, you are almost certain to find Pea Shells and Orb Shells. Take them home in a tin with a little mud or water weed and put them in a dish with pond water. When they become active, examine them to find out how many siphons they have. If an animal has only one, it will be a Pea Shell; if two it is an Orb Shell. Usually the Orb Shells will be more than ⅛ inch long, and in addition the umbones in Orb Shells are in the middle of the hinge edge, whereas in Pea Shells they are not quite in the middle.

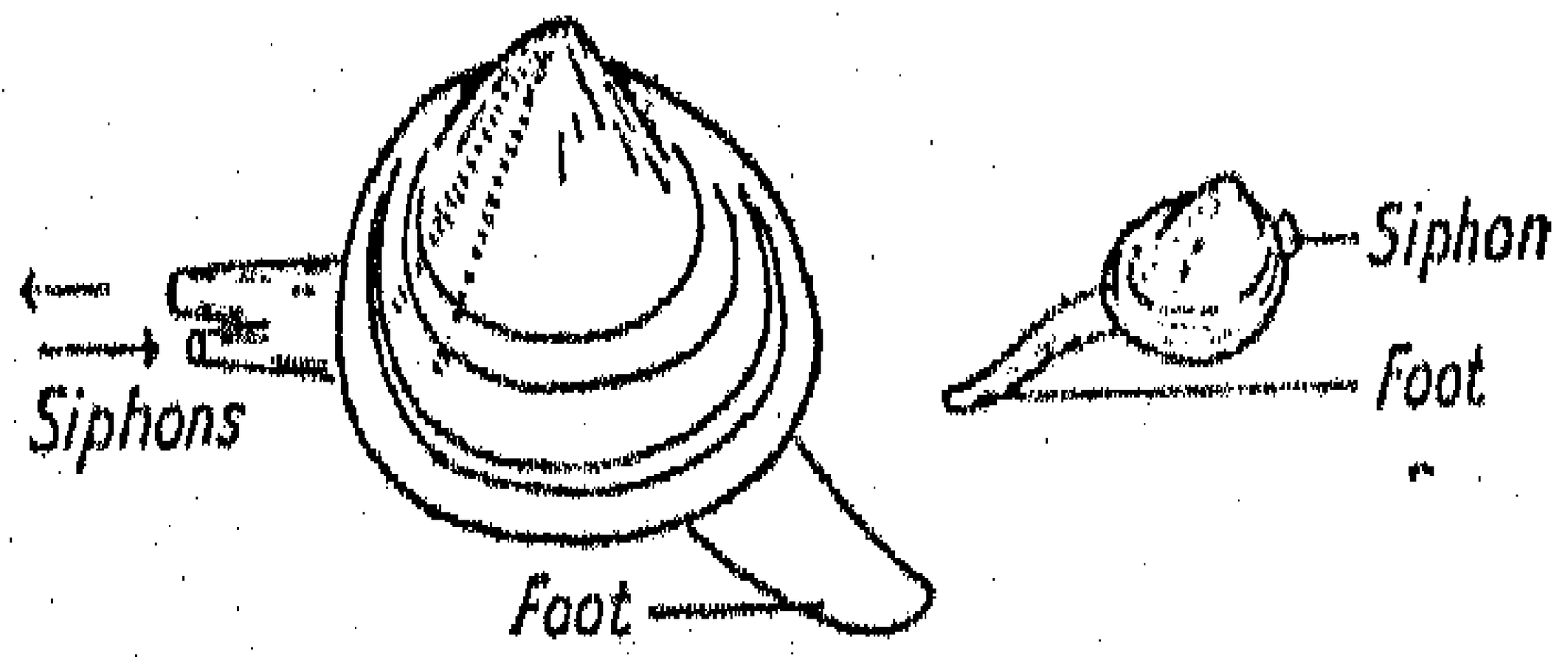


FIG. 52.—*Left:* An Orb Shell, *Sphærium,* ×2. *Right:* a Pea Shell, *Pisidium,* ×2 . Live specimens lying on sand.

KEY TO THE GENERA OF FRESHWATER BIVALVES

1	Shell usually large; umbones placed near the end of the hinge edge	2
	Shell less than ½ inch; umbones placed near the middle of the hinge edge	3
2	Depression in front of the umbone	*Unio*
	No depression in front of the umbone	*Anodonta*
3	One siphon; shell not more than ⅛ inch; umbones not quite central	PEA SHELLS (*Pisidium*)
	Two siphons; shell up to ½ inch; umbones central	ORB SHELLS (*Sphærium*)

Collecting Shells

It is very interesting, especially if you go to different places for holidays, to make a collection of shells. If you obtain live animals, they may be killed by dropping them into boiling water. The flesh can then be extracted from the shells by means of a pair of forceps, or with a pin.

Very tiny shells are best kept either in little glass tubes with corks (aspirin tubes plugged with cotton wool will serve very well), or on cotton wool in match-boxes. Each match-box can be divided into four compartments for the smallest shells by slips of cardboard. Every shell should have a label attached stating its place of origin, and its name as near as you can tell.

The shells of slugs, which you will have to dissect from the drowned animals (see p. 75), are best kept mounted on black paper, such as is supplied around photographic paper. They can be conveniently glued on with the same gum as is used for insects (see p. 152).

It is instructive just to make a collection of as many shells as you can, but still better to make collections from various habitats (a habitat is a place where animals and plants can live). The type of shells you get from chalk country are different from, and much more numerous, than the shells you get from land not overlying chalk. Natural chalk is calcium carbonate, and is not at all the same as blackboard chalk which is an entirely different substance.

In certain types of wood, e.g., pine, you will find very few snails, possibly because of the lack of calcium carbonate which the snails require to make their shells. I once found five tiny snails in a pine wood at Peaslake in Surrey, and all were on the broken shell of a thrush's egg. The egg-shell is made of calcium carbonate and the snails seemed to be gnawing it.

I suggest you try to make separate collections from

(1) The seashore
(2) Chalk country
(3) Non-chalk country, including woods
(4) Water.

If you are not likely to visit chalk country, try to get in touch with another naturalist who lives there and exchange specimens. I have no doubt that if you wrote to the biology master of one of the schools in a chalk area, he would put you in contact with a local naturalist, or one of his pupils, who would be glad to exchange specimens.

CHAPTER NINE

Earthworms and Leeches

Earthworms

EARTHWORMS may be obtained by digging in moist soil, or, better, by searching for them with the aid of a light on warm damp nights. At these times they leave their burrows and crawl about on the surface of the soil, or remain with only the tail in the burrow, the rest of the body lying stretched over the ground. If you move stealthily, you should see a good number of worms, on a suitable night, lying thus on a lawn or patch of moist soil.

As soon as a worm lying in this way is touched, it will withdraw rapidly into its burrow, so that you will have to pounce on it quickly and firmly. When you have grasped the worm, do not be in too great a hurry to pull it from its burrow or it will break. Apply a steady pull and gradually it will yield. You will probably be surprised to find how strong an Earthworm is.

When you have obtained two or three worms, find another that is lying quietly and then stamp on the earth about three

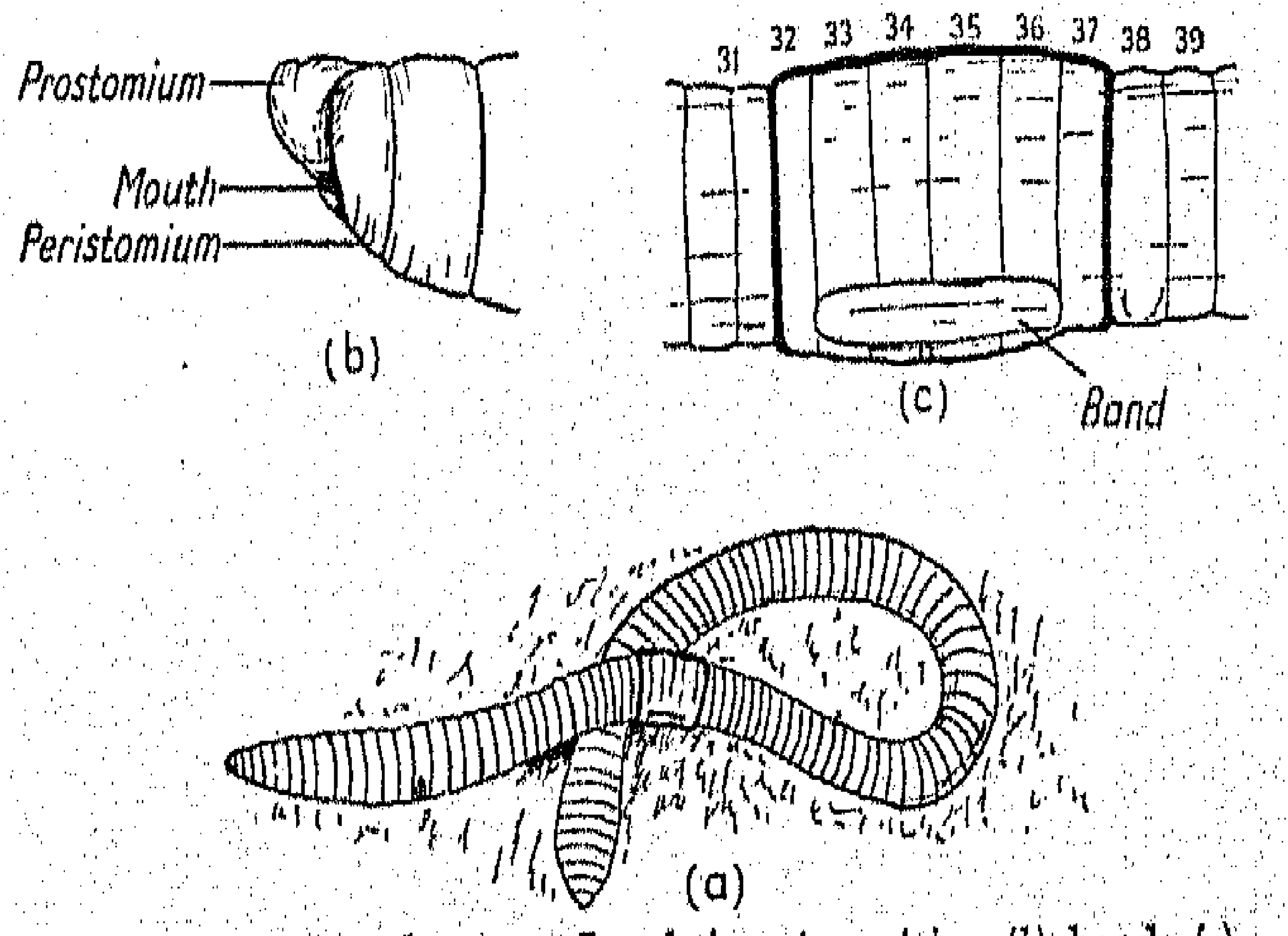


FIG. 53.—(*a*) Earthworm, *Lumbricus terrestris*; (*b*) head; (*c*) saddle region drawn from the side. (*a*) ×½, (*b*) and (*c*) ×3.

feet away. The worm will disappear at once, showing that it is sensitive to vibrations of the earth. On the other hand, these worms do not usually respond at once to the light from a torch. However, if the light is brought close, or concentrated on the front end of the worm by means of a lens, the worm will react by withdrawing into its burrow, either entirely, or leaving just its anterior end protruding. The stamping experiment should tell you that you must tread very gently while you are investigating the reactions of worms to light.

The general appearance of an Earthworm must be familiar to everyone, but there are some details of structure you may not have noticed.

There are many different worms, but the two largest are the Earthworm, *Lumbricus terrestris* (lum-bre-kus ter-res-tris), and the Long Worm, *Allolobophora longa* (al-lo-lobe-o-for-a lon-ga). The Earthworm will be described first, and then the way in which the Long Worm differs from it.

The EARTHWORM is large, from 4 inches to 10 inches in length. Its body is long and slender. At the front end it is a dark reddish chestnut in colour. The tail end is paler, except at the extreme tip where there is usually a little red colour. The under surface of the worm is paler than the top surface.

The body is divided into about 150 segments by grooves running right round it. At the front end the segments are more or less cylindrical but, from near the middle to the tail, the segments are flattened from the dorsal to the ventral surface.

At the front tip of the worm is the mouth, and at the extreme hind end of the body is the anus. The mouth is underneath a little lobe, called the prostomium, which fits into the first segment as shown in Fig. 53(*b*), so that it forms a kind of porch over the mouth.

On each side of segment 15 (counting from the front end) is a pair of yellowish lip-like swellings surrounding a small hole. These holes are the openings through which the male reproductive cells are passed during mating (see p. 93). The female reproductive cells are passed out through two smaller holes, one on each side of segment 14. Further back, on segments 32-37 is a prominent fleshy swelling called the saddle. On the top surface of the saddle there is often no sign of the segments, but, on the ventral surface, the segments can always be seen.

On each side of the saddle, about three-quarters of the way down, is a groove running along from segment 33 to segment 36 (Fig. 53*b*). The saddle makes the cocoon which will enclose the eggs when they are laid, but we shall come to this later (p. 93). Young worms do not have a saddle.

If you hold a live Earthworm in your fingers, you will be able to see two double rows of tiny glistening spines on each side. These are called *setæ* (see-tee) and the worm can draw them in or push them out from its skin, as it wishes. If a worm desires to move forward in its burrow, it pushes out the setæ at the tail end until they grip the walls of the burrow. When it is firmly anchored, the worm stretches out its front end, having first withdrawn the setæ in that region, so that they do not interfere with the forward movement. When the worm is fully stretched, it pushes out the setæ at the front end so that they grip the walls of the burrow and then withdraws the setæ at the hind end. Now it can draw its tail

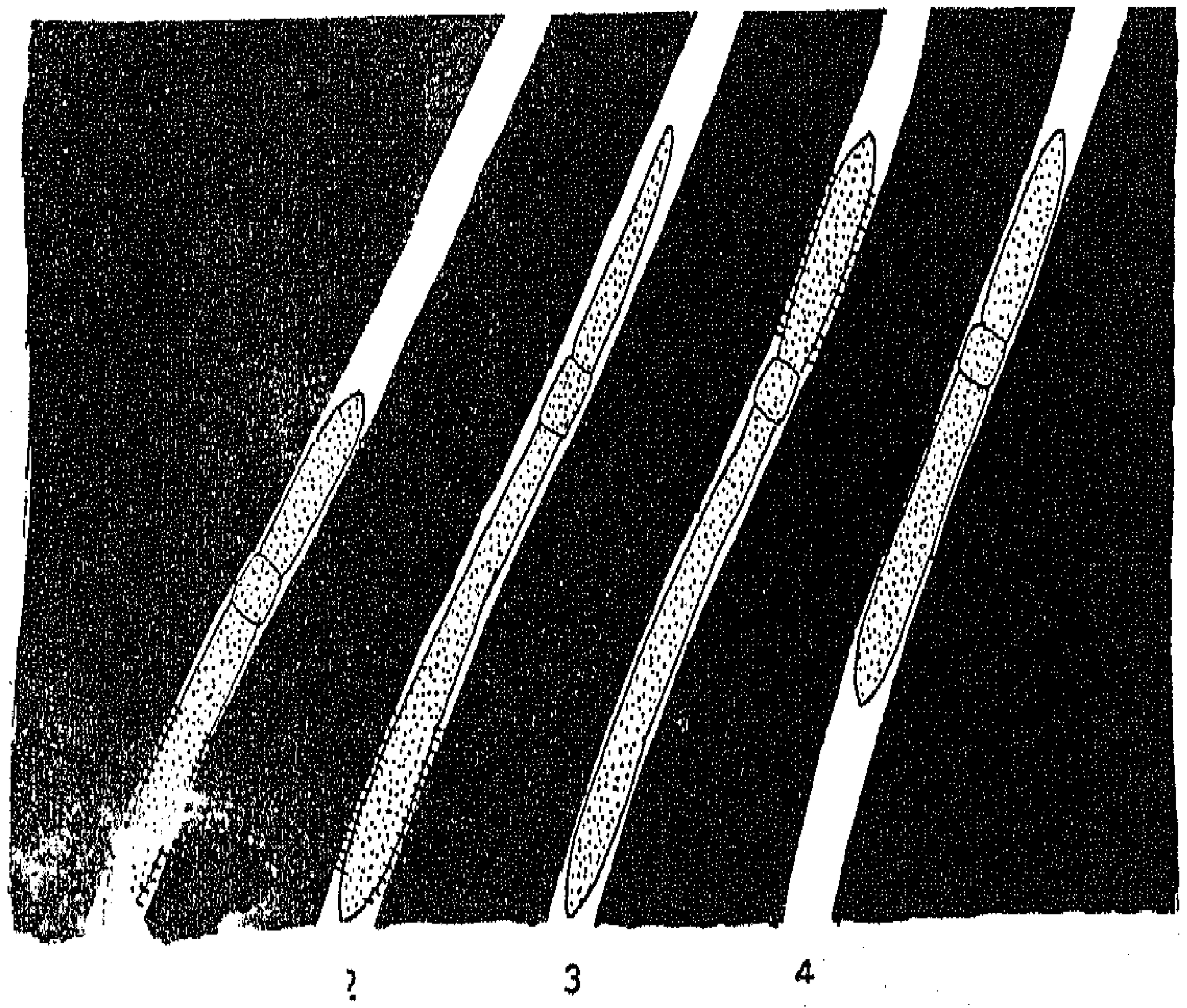


Fig. 54.—Diagram to show the manner in which the setæ assist the locomotion of the worm. (1) the setæ of the hind part of the body are protruded to grip the soil, while all other setæ are withdrawn; (2) the front region of the worm elongates; (3) the front setæ are now protruded, while the hind setæ are withdrawn; (4) the hind end of the body is drawn forwards, and so the whole of the worm has moved upwards in its burrow.

towards its head, and so will have moved a short distance (Fig. 54). This sounds a little complicated, but, if you watch a worm crawling over a piece of rough paper (e.g., newspaper), you will see how it is done, and you will find out that, although the worm normally moves with its head going forward, it can move backwards equally well.

If you look at the top surface of the Earthworm, you should be able to see a thin red blood vessel running along the length of the worm in the mid-line and lying just below the skin. It is rather irregular in outline and in a live worm you should be able to see the blood being pushed forward along it. There is a similar blood vessel below the skin in the mid-line of the ventral surface, but this is often not so easy to see and is of a rather bluish colour.

The skin of the Earthworm is moist and slimy. If the skin becomes dry the worm dies, because it breathes through its skin but can do so only as long as the skin is moist. One worm in a tin will soon die because its skin dries up, but a number of worms in a tin together roll themselves into a tight ball and will live a long time because each worm then dries more slowly. Worms I use as fishing bait often roll into a firm ball when the moss in which I keep them becomes dry.

Earthworms live most of their lives below the soil. They make burrows in the earth by pressing in between the particles where the soil is loose, or, where it is firmer, by eating the soil as they go along. At first sight, you might think they could eat the soil with their mouths and simply pass it out behind through the anus, but this is not so. You may have noticed that when a hole is dug in the garden [illegible] the road and then filled in again there is always some soil [illegible]—i.e., there is more than is required to fill the hole to the original level. The reason is that the particles in undisturbed soil are packed together very tightly—what is called NORMAL PACKING—and take up the least possible amount of space. When soil is dug up, the normal packing is disturbed and the soil particles take up more room than before. It takes such soil a long while to settle back to normal packing, a process much helped by rain.

A worm making a new burrow disturbs the normal packing of the soil in this way. By many species of worms, the surplus soil is brought to the surface and voided through the anus to form the coiled worm casts so frequently to be seen on healthy

lawns, football pitches, tennis courts, and other pieces of turf. *Lumbricus terrestris*, however, does not make casts, but disposes of the surplus soil underground. Worm casts are made of very fine soil particles indeed, and are soon washed flat by the action of rain.

At night worms frequently pull dead leaves into their burrows, and bunches of such leaves may often be seen jammed in the mouths of the burrows. The leaves are eaten by the worms, after being softened by a juice given out through the worm's mouth. Even stiff leaves such as holly are eaten.

During very dry weather worms go deeper into the ground, often as far as 6 to 8 feet down. The burrows help to drain the soil as well as to allow air to enter it. Both these circumstances improve the soil for plants, and most farmers know that the presence of many earthworms usually indicates a fertile field.

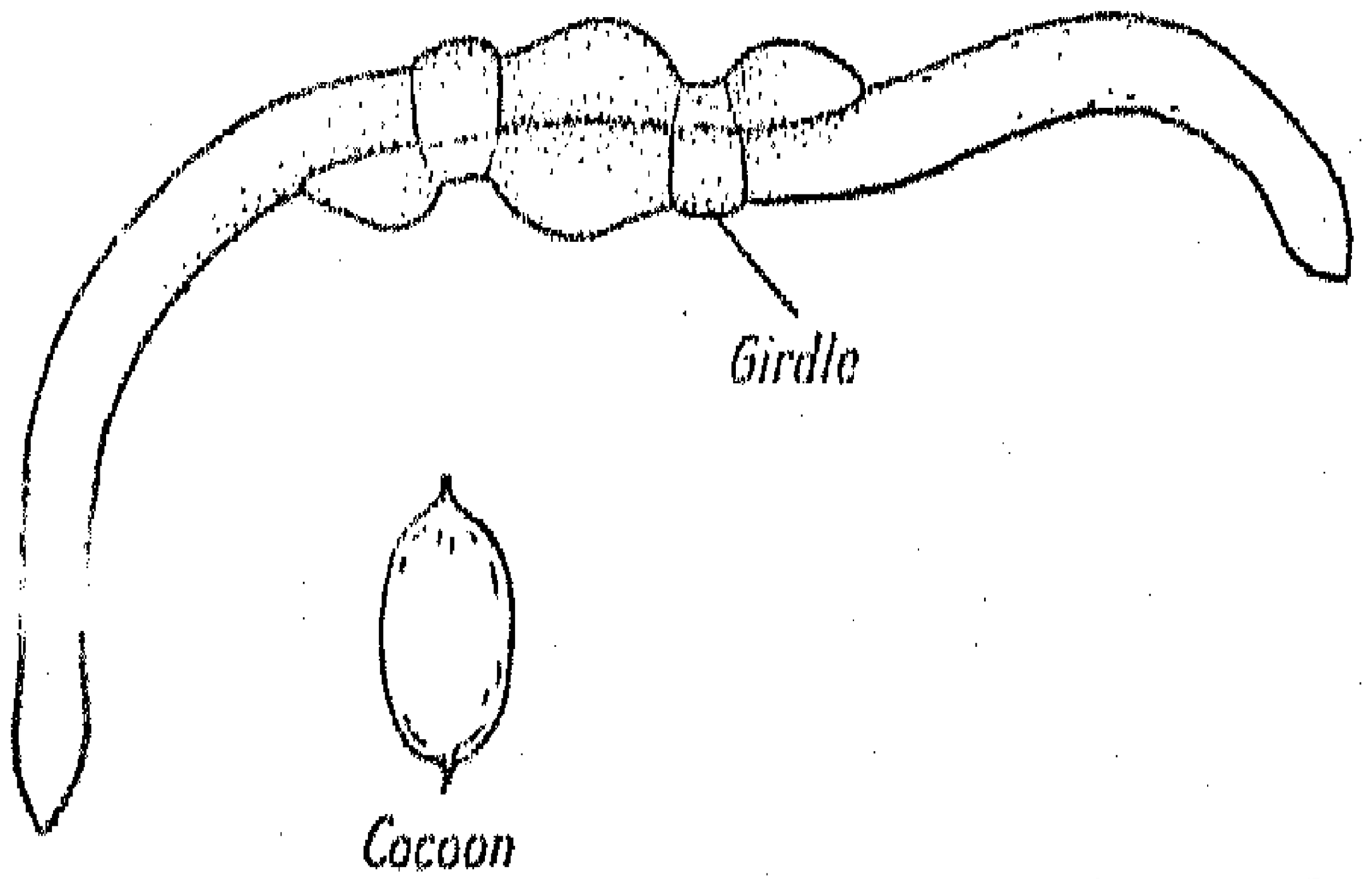


FIG. 55.—*Above:* worms drawn during mating on the surface of the soil, ×½. *Below:* A cocoon, ×2½.

Earthworms mate on the surface of the soil, usually at night, but sometimes on damp mornings, especially in the autumn, you may find two worms lying on the surface with their head ends side by side but the tails pointing in opposite directions (Fig. 55). Closer observation will show you that the front portions of the two worms, extending beyond the saddles, are bound together by slimy tubes in the regions of the saddles. While thus bound together, the worms exchange male reproductive cells, which later on fertilise the eggs.

After the exchange of sperms, the worms separate. A few days later the saddle makes an elastic "cocoon" round itself, and eggs from the worm now pass into the space between the cocoon and the body of the worm. Next, the segments immediately behind the cocoon swell up and push the cocoon forward. This process continues until the cocoon is pushed forward over the end of the worm, when its two ends close up and it forms a brownish lemon-shaped body rather less than ¼ inch long. Before it is finally pushed off from the body of the worm, sperms have also been passed into it.

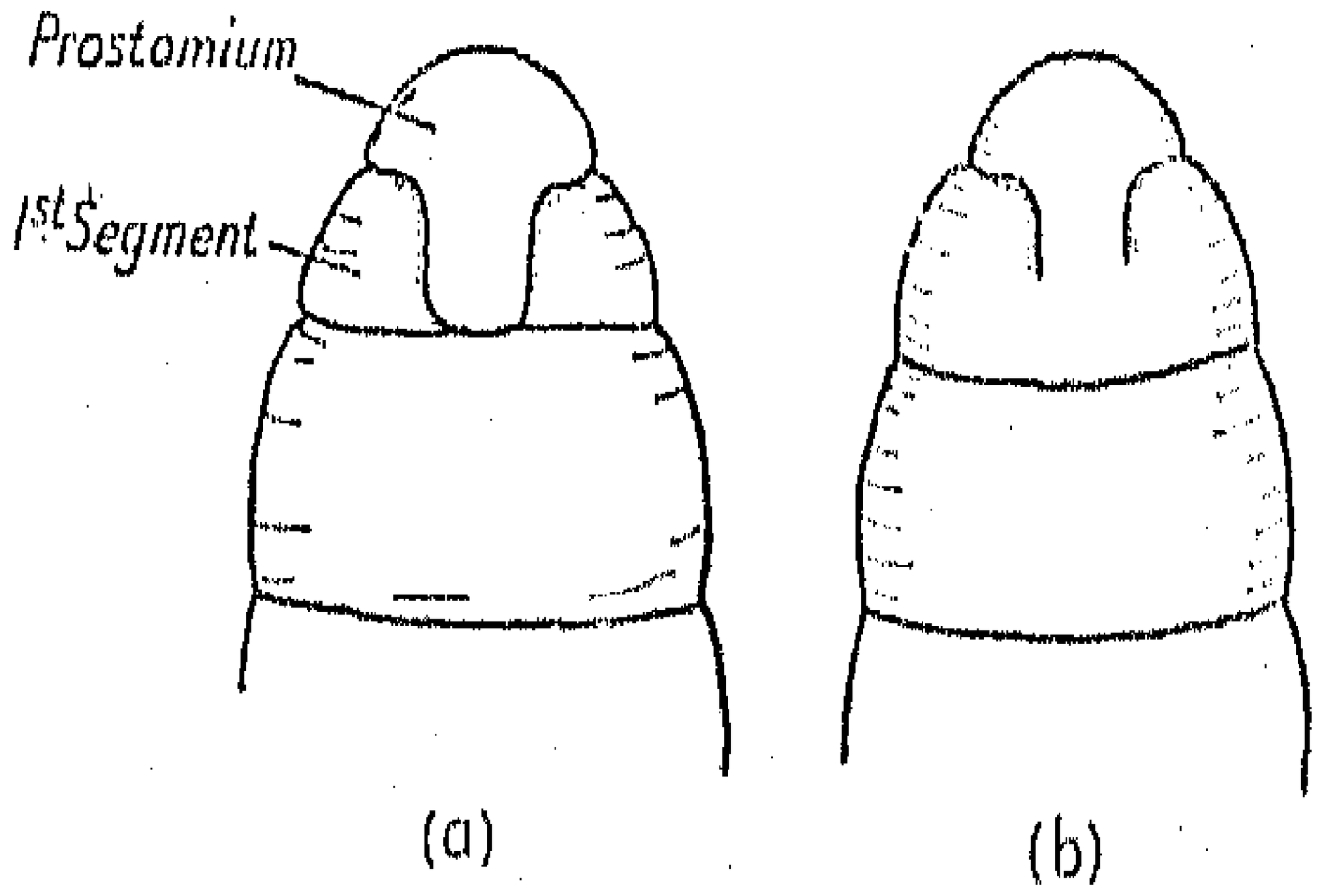


FIG. 56.—Dorsal view of (*a*) head of Earthworm, and (*b*) Long Worm, to show the nature of the prostomiums. (Enlarged.)

Inside the ripe cocoon is a white fluid containing the eggs and sperms, but these are too small to be seen without a microscope. The eggs are fertilised by the sperms and begin to grow, feeding on the white liquid, but usually only one egg succeeds in developing into a little worm.

THE LONG WORM differs from the Earthworm in colour, in the position and length of the girdle, and in the way the prostomium is fitted into the first segment (Fig. 56). These differences are given in the table below.

DIFFERENCES BETWEEN THE EARTHWORM AND THE LONG WORM

	EARTHWORM	LONG WORM
Colour	Dark brownish red or violet at the front, paler greyish tail; clean and fresh looking	A dirty brown at the front, grey at the hind end; rather muddy looking
Position of girdle	On segments 32–37, six segments long	Eight or nine segments long, from 27 or 28 to 35
Nature of prostomium	The hind end of the prostomium reaching to the rear border of segment 1 (Fig. 56*a*)	The hind end of the prostomium reaching only about half-way across segment 1 (Fig. 56*b*)

Leeches

In most stretches of fresh water (canals, ponds, and streams) leeches are to be found. These animals are closely related to worms, but differ in that the body is usually much flattened from the dorsal to the ventral surface, and each leech has a sucker on its under surface near the tail end. There is another sucker surrounding the mouth which is at the front end, but this sucker is not always clearly visible. As with earthworms, the body is divided into segments, but, unlike those of earthworms, each segment is further divided by grooves running round the body.

Most leeches can swim quite well by a wave-like motion of the body, but often they move over solid surfaces by means of their suckers (Fig. 57). A leech moving in this latter manner takes a firm hold on the solid surface with its hind sucker and stretches the body out in the direction it wishes to travel. When it has obtained a grip with the front sucker, the hind sucker releases its hold and the tail end of the body is brought up to the front end. In this way it proceeds by a series of loops very much like a "looper" caterpillar (see p. 137).

Visible on top of the head are a number of dark spots. These are the eyes. There are five pairs in the Horse Leech (Fig. 57), one of the commonest leeches, but the number of eyes varies in the different species. Owing to the presence of pigment in the skin the eyes are not always clearly visible. They may often be made more distinct by soaking the leech in weak caustic soda solution.

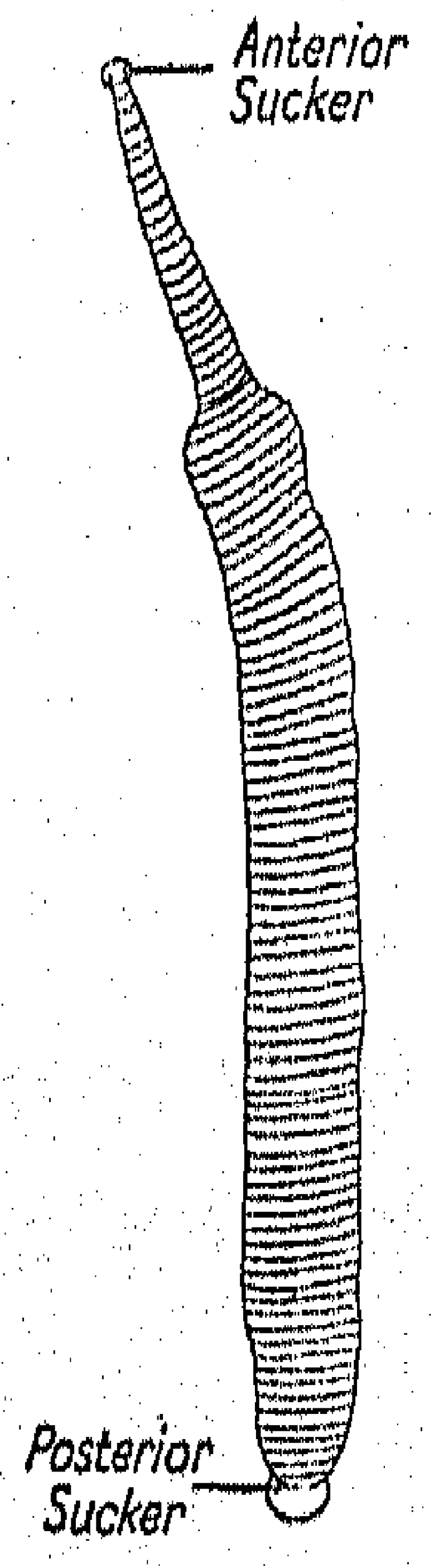


FIG. 57.—The Horse Leech, ×1.

The skin is usually some shade of brownish green, but leeches have the power of changing colour to some extent to match the colour of their surroundings. Most leeches obtain their food by sucking blood from other animals, such as snails, freshwater mussels, fishes, worms, and even water birds. A few leeches do not suck blood but devour their prey completely.

Leeches vary in length from 2 or 3 inches to about ¼ inch. They may be found on the mud at the bottom of ponds or attached to stones or other solid objects on the bottom of slow streams. The smaller ones especially are often to be found attached to water plants. I have found the stems and undersurfaces of water-lily leaves a favourite place. These smaller leeches look like tiny masses of brownish jelly clinging to the plants, but will begin to move if left undisturbed for a short time.

Leeches, like earthworms, are "hermaphrodite", that is, each leech is both male and female. Some leeches (e.g., the Horse Leech) leave the water to lay their eggs in damp earth, but, in some other species, the eggs are carried about on the undersurfaces of the adults, while yet another group attach their eggs to stones and water plants.

In former times, doctors believed that many illnesses were due to the presence of too much blood, and it was very fashionable to try to effect cures by "blood-letting". One way of doing this was to allow hungry leeches to feed on the patient. Special Medicinal Leeches were used. These leeches have sharp teeth that can easily pierce human skin. When placed on a patient's arm they would make a neat hole in the skin, suck blood until they were fully gorged, and then drop off. At one time Medicinal Leeches were common in England, but now they are absent from most parts, though they are to be found in fair numbers near Brockenhurst in the New Forest.

The following species of leeches are common. Unfortunately most of them have no English names.

COMMON SPECIES OF LEECH

(1) With 5 pairs of eyes:

The Horse Leech, *Hæmopsis sanguisuga* (he-mop-sis san-gwe-sewj-a.)

Colour varies from a darkish green to brown; five pair of eyes; about 3 cms. long when at rest, but can extend to 3 or 4 times that length.

(2) 4 pairs of eyes:

Herpobdella octoculata (her-po-del-la oc-to-kewl-ay-ta.)

Usually dark brown, but sometimes a yellowish or reddish brown with black markings; four pairs of eyes; length about 3–4 cms. at rest.

(3) With 2 or 3 pairs of eyes:

(a) *Glosso-siphonia complanata* (gloss-o-si-fone-e-a kom-pla-nate-a.)

Dark greenish brown in colour with six rows of cream coloured spots (as a rule); usually three pairs of eyes, but the first pair may be very small or absent; length about 3 cms. when moderately stretched out.

(b) *Glosso-siphonia hetero-clita* (gloss-o-si-fone-e-a het-er-o-klite-a.)

Clear amber yellow, with the back often thickly sprinkled with dark coloured spots; three pairs of eyes, but the front pair may not be black; length about 1½ cms.

(4) 1 pair of eyes:

Helobdella stagnalis (hee-lo-del-la stag-nay-lis.)

The colour is a greenish grey, sometimes with a pinkish tinge, with very fine black specks on the back. One pair of rather large eyes placed near the mid-line; size, about 1 cm. long.

CHAPTER TEN

Hydra

IF, during the summer months, you collect water weeds from ponds, canals, or lakes, and place them in jam-pots with water, after a day or so you are almost certain to find specimens of the curious animal called *Hydra* (hy-dra) clinging to the walls of the jar, especially on the sides nearest the light.

Hydra is a rather small creature capable of changing its shape considerably. When touched or shaken, it shortens its body until it is no more than a tiny pin-head of jelly-like substance, but, if left undisturbed, the *Hydra* will gradually expand and will be seen to have a thread-like body with a ring of delicate tentacles at one end (Fig. 58*a*). We call this the front end of the body. The other end is called the base and it is usually fixed to some solid support such as the leaf or stem of a water plant, or the walls of an aquarium.

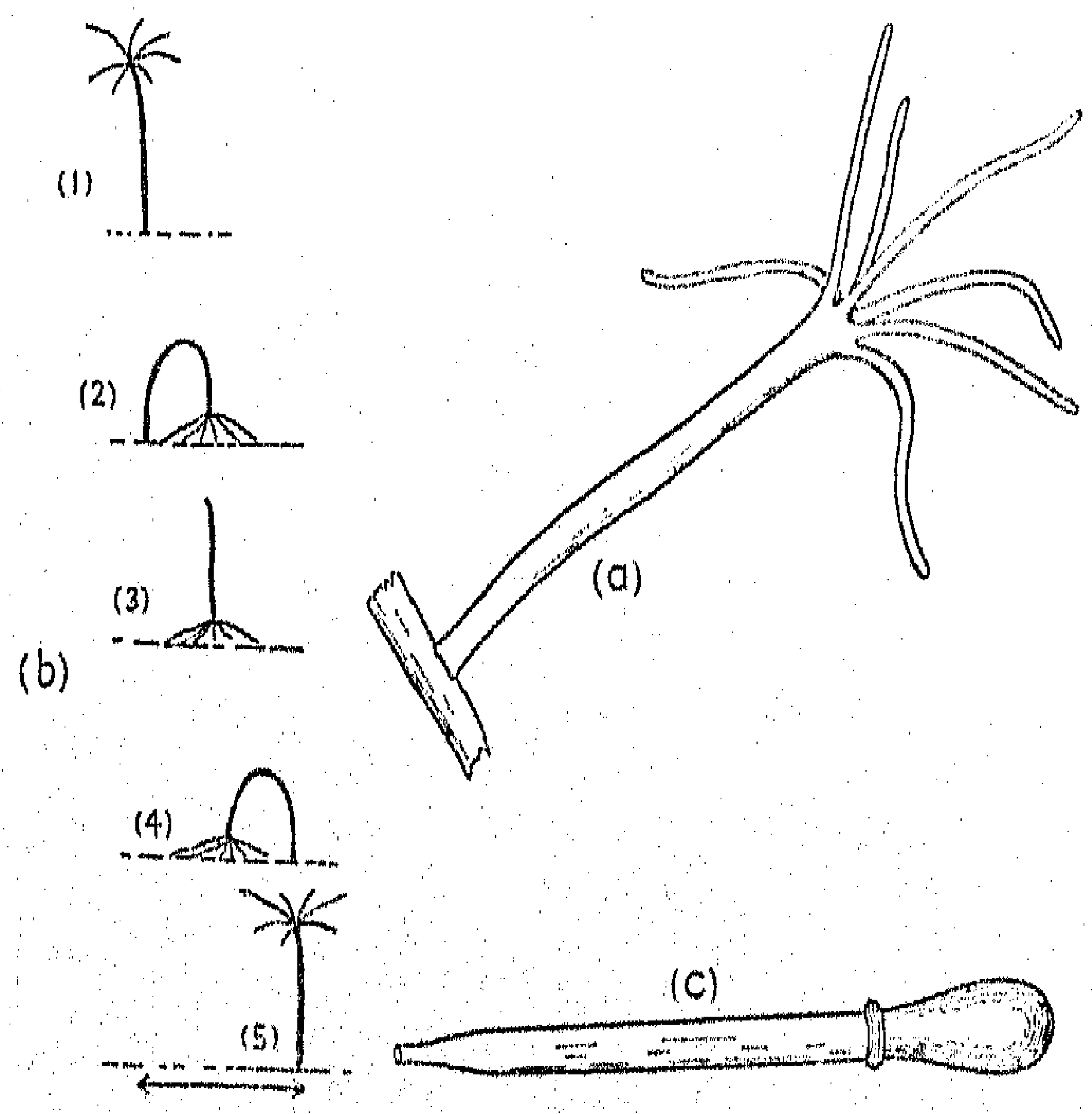


FIG. 58.—(*a*) *Hydra*, ×20; (*b*) diagrams to show the method of looping in *Hydra;* (*c*) glass pipette for catching small aquatic organisms.

The body can become extremely long, often as much as 2 inches, and then it is so thin that it is hard to see. Usually the body is between ¼ inch and ½ inch long, and about as thick as sewing cotton, with the tentacles a little thinner. But, as I have already said, the length, and so the thickness, change considerably.

There are three kinds of *Hydra* found in Britain, the Green, the White, and the Brown, though both the White and the Brown Hydras may sometimes be rather greyish, and then they are difficult to tell apart. The bright green of the Green Hydra is very distinct and this species cannot be mistaken for any of the others. The White *Hydra* is not as common as the other two.

The number of tentacles varies from specimen to specimen, but seven is a common number. The tentacles are situated with their bases forming a ring around the mouth, but the mouth is not easy to see, even with a hand lens, although you may sometimes see the tentacles pushing food into it. There are no other openings on the body, which consists merely of a cylindrical wall enclosing the food cavity or "stomach". Unused food particles have to be voided through the mouth.

The tentacles of the *Hydra* are covered with many tiny "stings" which are capable of paralysing small water creatures such as *Cyclops* and Water Fleas (p. 193). The "stings" also act as small harpoons, so that the bodies of the tiny creatures that have been stung stick to the tentacles.

If you put several *Hydras* in a small glass tube, it is quite easy to watch them feed by adding a number of small crustaceans (p. 192) that you may have collected with a water net or reared in a culture. You will see a Water Flea, for instance, swim into the net of outspread tentacles and, as soon as it touches one, stop quite still, as if it had been stunned. Sometimes the *Hydra* will push it into its mouth with its tentacles; on other occasions, possibly because the *Hydra* is not hungry, it will release the prey after a few seconds. Then the Water Flea will sink a little way in the water before it swims off, apparently none the worse. *Hydras* can be transferred from one vessel to another by means of a glass pipette (Fig. 58*c*) or by a long glass tube. To use glass tubing for this purpose, put a finger over one end and push the other end under water. Then, when you remove your finger, water will rush up the tube carrying with it any small objects. Whether you use a pipette or a glass tube, you may first have to push the *Hydra* from the sides of the jar, because sometimes they stick on very tightly. They are enabled to do this because the base secretes a gummy substance.

Hydra can move about slowly, by a kind of creeping movement of the base end, over the surface to which it is fixed. At other times *Hydra* may move by turning somersaults. The body is bent over in a loop until the tentacles are in contact with the support, and then the base end is released so that, in effect, the *Hydra* is now standing on its head. Now the base is bent over in the direction the *Hydra* wishes to travel until it gets a new grip on the support, and then the tentacles release their hold so that the *Hydra* is now standing the usual way up but in a new place (Fig. 58*b*). I have often seen Green Hydras do this up the wall of a jam-pot.

If *Hydras* are given plenty of food they will soon begin to reproduce by "budding". The first sign is one or more swellings on the sides of the *Hydra's* body. These grow rapidly and soon begin to develop tentacles, so that they now look like small *Hydras*. It is interesting to observe that the buds do not always have the same number of tentacles as the parents: there may be fewer or there may be more. Soon the region by which the bud is attached to the parent becomes narrowed, and ultimately it breaks through completely to set the bud free as a new *Hydra*. A well fed *Hydra* may have two or three buds on it at once. This type of reproduction, which merely involves the parent splitting off a part of itself, is called asexual to distinguish it from sexual reproduction. We saw (p. 36) that a similar kind of asexual reproduction occurs among the duckweeds.

It is possible, with a sharp razor blade, to cut a *Hydra* into two or three pieces and watch each piece grow into a new organism. If you do this, place the pieces in a small tube full of aquarium or pond water in a window. The pieces should be quite visible and in a few days you should see that each piece has formed itself into a complete small *Hydra*. The ability to grow new parts in this manner is called the power of regeneration, and is possessed by many of the simpler plants and animals. Human beings have this power only to a limited extent. We can grow new skin over a wound, but cannot grow a new hand, or eye, or even a new tooth in our permanent set.

In autumn the natural food supply of *Hydra* becomes less plentiful and the water gradually becomes colder, with the possibility that shallow ponds will be completely frozen. In response to these changes, *Hydras* reproduce themselves in a different way. Each *Hydra* produces eggs and sperms in separate little swellings that can be seen on the body wall. The ovaries are usually near to the base of a *Hydra*, while the *testes* (tes-tees: singular *testis*) are near the head end.

The sperms are very tiny indeed, much too small to be seen with a hand lens, and very many are produced in each testis. They are rather like very slender tadpoles and can swim about by wriggling their tails. They swim about actively until they find a *Hydra* with a ripe egg in its ovary (each ovary usually produces only one ripe egg) and then one sperm joins up with the egg, burrowing into it and merging with it completely to fertilise it. Sperms that do not succeed in finding an egg soon die. The fertilised egg now begins to develop until it is a little rounded body, still very tiny, with a protective covering around it. In this state it falls from the ovary to the bottom of the pond, where it passes the winter. Next spring it continues developing and grows into a young *Hydra*. The old *Hydras* usually die in the autumn before the onset of winter, so these resting bodies, made from fertilised eggs, are all that remain to carry the *Hydra* species from one season to the next.

The group to which *Hydra* belongs is called the *Coelenterates* (see-len-ter-ates). Other members of this group are the jelly fishes you may sometimes see cast up on the sands at the seaside, and the sea anemones, which you can find in rock pools on the shore or stuck to rocks between high and low tide marks. If you are staying at the seaside, where there is a rocky shore, you should be able to find sea anemones clinging to rocks, particularly rocks that are covered with the usual brown seaweed. If you lift the seaweed (notice how damp it is beneath) you will find the anemones, which appear as lumps of rather stiff jelly of a reddish or brownish colour, often with spots of brilliant blue. The body wall will be tightly contracted and the tentacles hardly visible. If you pull a few anemones off the rocks and take them home wrapped in seaweed, the anemones will gradually expand when you leave them undisturbed in shallow bowls of seawater. You will then see that they have two or more rings of tentacles with the mouth in the centre. It is usually not difficult to persuade them to eat small pieces of raw meat placed on the tentacles.

You will find that sea-water stood in a dish rapidly goes foul, so you must change it for a fresh supply every day if you wish to keep the anemones for any length of time. Fresh water obtained from the tap is of no use, because it kills sea animals very quickly: seawater *must* be used.

CHAPTER ELEVEN

The Insect Pattern

Insect Structure

IN every-day speech, many different kinds of creatures that are small and have a number of legs are referred to as insects. To the biologist, however, the word insect has a definite meaning; and it will be best, before we study the several different types of insects, to get a clear idea of what characters an animal must possess before it can properly be called an insect.

All insects have a fairly rigid body wall made in part of a substance called *chitin* (ky-tin) which acts as a skeleton and supports the organs of the insect. The body is divided into three main regions which usually are quite distinct. These are the head, thorax, and abdomen (Fig. 59). The head is at the front end, the thorax comes next, and the abdomen forms the "tail" part. Each of these three parts is itself divided into smaller sections called segments, but as a rule these smaller segments can be clearly seen only on the abdomen.

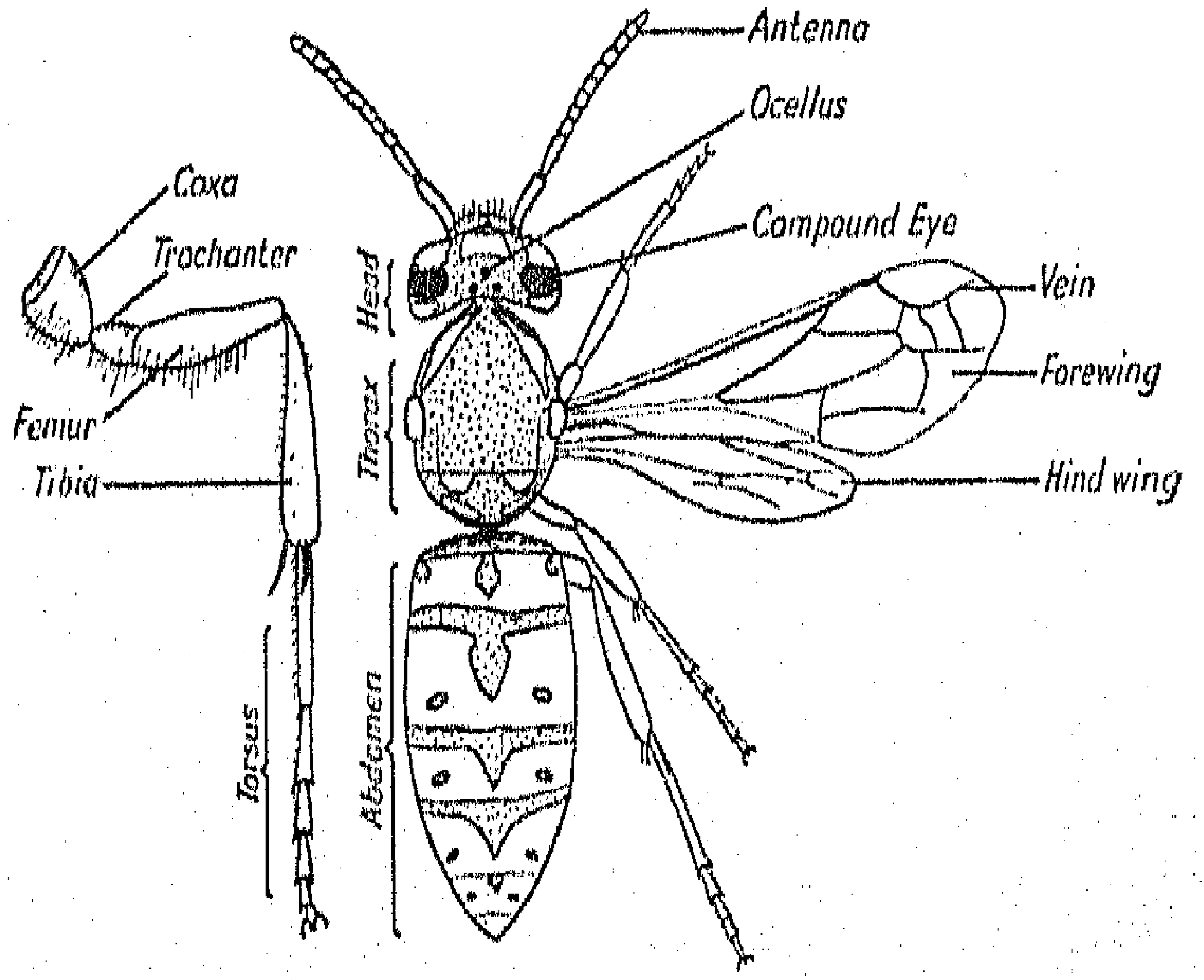


FIG. 59.—*Right:* German Wasp (*V. germanica*), ×3; *left:* hing leg of German Wasp, to show the various segments, ×5.

On the head there is present a pair of feelers, or, as they are more properly called, antennæ (singular: antenna) which are made up of many segments. Their exact shape varies in different insects. They may be simple threads, or branched, or feathery, or be thickened at the end. Some beetles have a club made of several plates at the free end (Fig. 76*c*). The antennæ are sense organs and are used by the insects for smelling and feeling. In addition to the antennæ, the head carries jaws and eyes.

Usually insects have a pair of large eyes, one on each side of the head. These are peculiar in that each complete eye is made up of very many tiny eyes all fitted closely together to form one structure, so that the surface of the eye looks rather like an old-fashioned window with many small panes all roughly the same shape and size. These little "window panes" are called facets, and can be seen fairly easily with a magnifying glass. Such eyes are called compound eyes. They occur in some crustaceans (p. 192) as well as in insects; but certain insects (e.g., ants) do not have them. They are especially large in dragonflies (Fig. 97).

In addition to compound eyes, most insects have simple eyes. These are very much smaller. Each simple eye consists of a single lens which directs light on to a sensitive area just beneath it. There are usually three simple eyes arranged on top of the head of the adult insect to form the three corners of a triangle, as shown in Fig. 59. Simple eyes are not present in all insects.

The jaws, or mouth parts, are a series of structures surrounding the mouth opening, and they assist in feeding. Their forms vary very much, according to whether they are used for sucking (e.g., in flies and moths), piercing (e.g., in mosquitoes and greenflies), or biting (e.g., in wasps and many beetles). We shall meet the various types later, when we study particular insects.

The head is connected to the thorax by a neck, more or less distinct. The thorax is always composed of three parts or segments, but these cannot always be distinctly seen, as they are firmly united to one another. Each segment of the thorax bears a pair of legs, so that there are six legs in all, and this fact is a great help in deciding whether or not a specimen is an insect. The legs are jointed, and the various joints are so arranged as to give the legs great freedom of movement. There are usually nine segments in each leg. The names of these are shown in Fig. 59. The last few segments make up the foot or *tarsus* and usually the end segment of the tarsus bears one or more claws.

As a rule, each of the two hinder segments of the thorax bears a pair of wings, but in some insects one pair of these does not look much like wings (p. 153). The wings are thin sheets of "skin" strengthened with stiff ribs called veins, and the arrangement of the veins is often a great help in naming an insect. Each group of insects has its own particular pattern of veins.

This type of wing is found in no other group of animals and provides an excellent means of recognising an insect. In a few kinds of insects, the wings are missing altogether (e.g., in fleas, worker ants, and some greenflies), but these can be identified as insects because they have six legs and one pair of antennæ.

The abdomen of insects consists of several segments, which usually can move slightly on one another. This is made possible because the skin where the joints occur is thin and pliable, not hard and rigid as it is elsewhere.

The breathing system must be mentioned briefly. Air is taken to all parts of an insect's body by a complicated system of air tubes called *tracheæ* (tray-ke-ee) which open on to the surface of the insect at special places. The openings are called *spiracles* and can sometimes be seen easily. The number and arrangement of the tracheæ and spiracles vary in the different groups of insects.

To sum up: a typical insect is an animal with a hard covering of chitin on the outside, and with its body divided into head, thorax and abdomen. It possesses three pairs of legs, two pairs of wings, usually both simple and compound eyes, and one pair of antennæ. Not all insects possess all these characters, but a pair of feelers and six legs are always present in the adults.

We will now study the wasp as an example of a typical insect, and then go on to deal with further types in the following chapters.

The Wasp

In summer wasps are abundant everywhere, and usually a number find their way into the house, where they may be caught on the window pane. The simplest way to do this is to place the mouth of a killing-bottle (or a tumbler) over the insect, and when it flies into the bottle, slip a piece of cardboard or stiff paper between the window pane and the mouth of the bottle. The lid can then easily be screwed on. You can also catch a good many at once by stirring a spoonful of jam with a little water and placing it out of doors in a jam-pot. Many wasps will drown themselves in the sticky liquid, but any not dead can be killed by adding boiling water. The sticky liquid should then be washed off the dead wasps with warm water, and, when the insects have dried, they will be suitable for study.

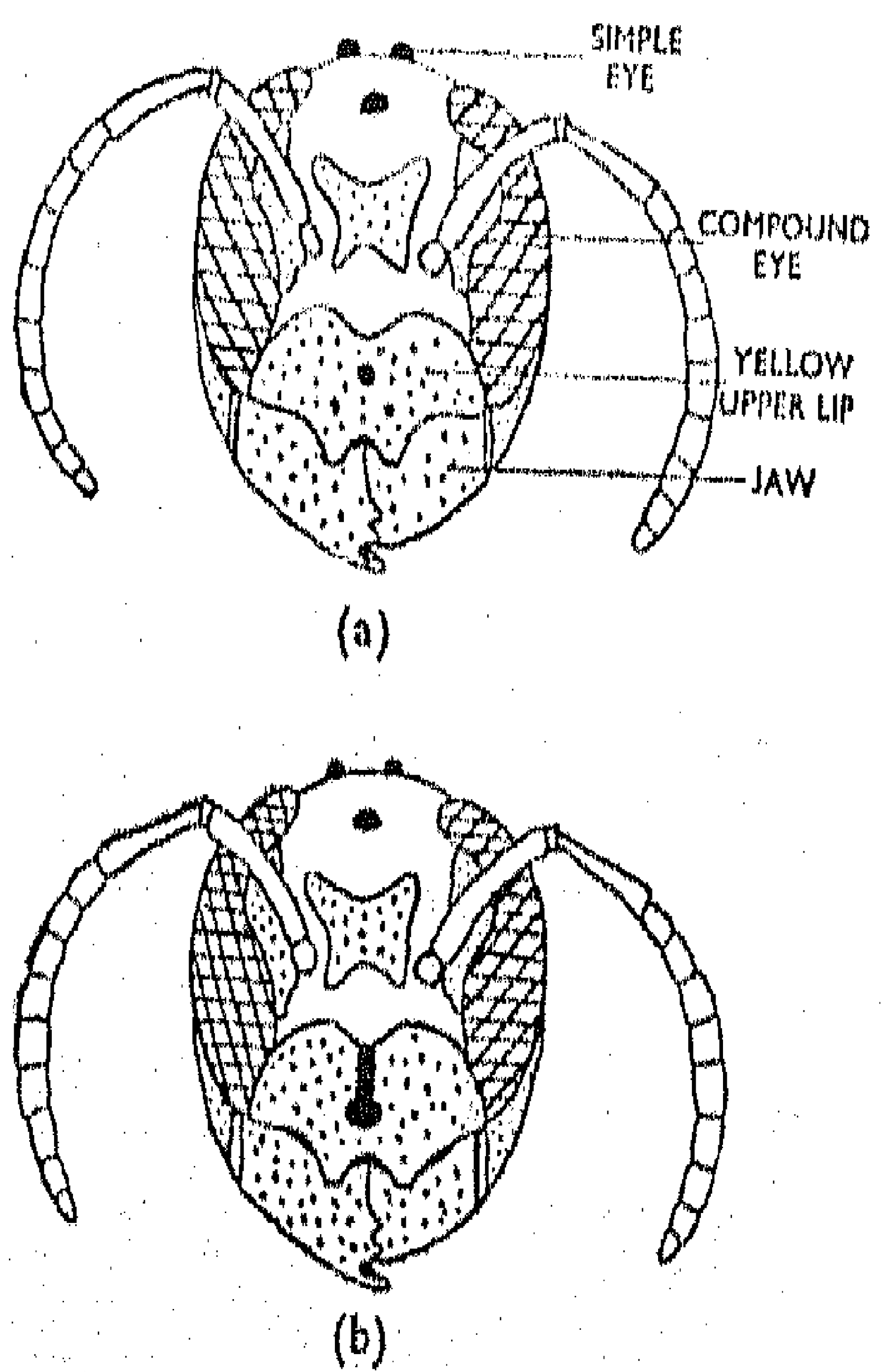


FIG. 60.—Face view of (*a*) the German Wasp (*V. germanica*) and (*b*) the Common Wasp (*V. vulgaris*). On the yellow upper lip of the German Wasp are three black dots, arranged at the corners of a triangle, whereas the yellow upper lip of the Common Wasp has a black anchor-shaped mark. (Both ×8.)

The body of the wasp is only thinly covered with hair, so the various parts are easy to see with the aid of a hand lens. The hard plates of chitin which form the body wall are very obvious, and the three parts of the body, the head, thorax, and abdomen, can be seen at once. The head is connected to the thorax by a quite narrow neck, and the thorax is similarly connected to the abdomen by a slender stalk which can be made visible by bending the abdomen downwards.

If you look at the "face" of a wasp from the front, you should be able to see the pair of antennæ, the compound eyes, the simple eyes, the top lip, and the powerful biting mouthparts or mandibles. The positions of these structures are shown in Fig. 60. The three simple eyes are more clearly seen if the head is observed from above, but a hand lens is necessary to see them clearly.

The compound eyes are very large. Each starts on top of the head and runs down one side, to end just above the base of the mandible of that side. Near the top, each eye has on its inner margin a deep notch or bay, in which the chitin is coloured yellow. The antennæ arise from near the mid-line on the upper part of the face. Each antenna has a long first segment, a very short second segment, a third segment about as long as the first, and then nine other segments about as long as one another and roughly one-third as long as the first (Fig. 60). That makes twelve segments in all. This is the number of segments in the antennæ of female wasps, and you are most likely to catch a female, especially in early summer. In the antennæ of male wasps there are thirteen segments.

The mandibles will probably be closed, but with a little patience you should be able to force them open by means of a pin; you will then see that they are quite stout pieces of chitin, the cutting edges of which are jagged rather like a saw. Each jaw has three big teeth and a number of smaller ones. Behind the mandibles are other mouth parts that can be used for licking up liquids. When you have forced open the mandibles, the shape of the upper lip will be more clearly visible.

On the thorax are the six legs, each with nine segments. The end segment carries a pair of fine claws between which you may be able to see a dark pad. Each *tibia* (see Fig. 59) carries a pair of prominent spines at the end furthest from the body.

From the top of the thorax there arises on each side a pair of wings. These may look rather narrow, because usually they are folded lengthwise. To see them more clearly, it is best to remove a pair from one side of the wasp and place them on a piece of white paper. It is best to wet the wings with spit so that they stick to the paper; otherwise they are liable to blow away. There is no difficulty with the hind wing, but the front wing is rather troublesome to open out. Lick the tip of your first finger to make it moist and place the wing on it. It should now be possible to unfold it with a pin, and it will lie flat because of the moisture. It is then easy to transfer it to the paper alongside the hind wing. You will now be able to see the pattern of the veins (Fig. 59). The two wings act together as one during flight, because the hind wing carries along its front margin a row of little hooks that catch on to the rear border of the front wing, making quite a firm connection. The hooks are rather small and not easy to see without a microscope; but as bumble bees also have these hooks, you will be able to study the device much better in them (Fig. 65).

The abdomen of a female wasp has six segments which can be counted. Actually there are eight segments belonging to the abdomen; but the first is a small one fixed firmly to the hind end of the thorax, and the second makes the connection between this and the six remaining segments. In this chapter, when I speak of the abdomen I am referring only to these six large segments. The joints between the abdominal segments are vible to the naked eye, and you can see that they allow each segment to move with respect to its neighbours. Each segment has two plates of chitin, a small one on the under-surface and a larger one, forming the side walls and top, which overlaps the small one at its edges. You will see that the body of the wasp is completely protected by this armour, and that there are no soft spots where it could be attacked by other insects.

The wasp carries its sting in its tail. Normally the sting is hidden inside the abdomen; but it is sometimes possible to see just the tip of the sting, which looks like a dark brown needle-like point, projecting from the very tip of the abdomen. This sting is really a much altered egg-laying tube, and is therefore absent from male wasps.

The life history of the wasp is interesting. At any time from the end of March until the end of May, you are likely, on sunny days, to see especially big wasps which are rather sluggish in their movements. These are queens that have passed the winter sleeping in some sheltered place—I sometimes find them among the junk in the garden shed during winter months. With the warmer days of spring, they become more active and, after a period of searching, find a suitable place, usually a hole in the ground, to make a nest.

As soon as a suitable site has been chosen, the queen wasp sets about gathering nesting material. This is usually wood which she rasps off with her strong mandibles. I have seen wasps eating away paper from notices pinned up out of doors, and a tennis club to which I once belonged found it impossible to keep notices on the out-of-doors notice-board because of this: but that was later in the season when there were many more wasps about. The material obtained in this manner is mixed with saliva, and forms a brownish, rather brittle, material known as wasp paper. The queen fixes this wasp paper to the roof of the chamber in which the nest is to be built, and the nest is constructed to hang downwards from the roof, to which it is attached by a central pillar. The queen first builds a horizontal sheet of "comb" which consists of several cells side by side and opening downwards (Fig. 61). Into each cell she lays an egg, fixing it there by means of glue. In a short while, the eggs hatch and the larvæ that emerge are fed by the queen. Soon the larvæ (or wasp grubs as they are usually called) are full-grown. Then each grub closes the open end of its cell with a sheet of silk that it spins from special glands under its head, and enters a resting state. From this it soon emerges as a fully-grown wasp and bites its way out of the cell, through the silk capping. The whole process takes about five weeks from the time the queen laid the egg.

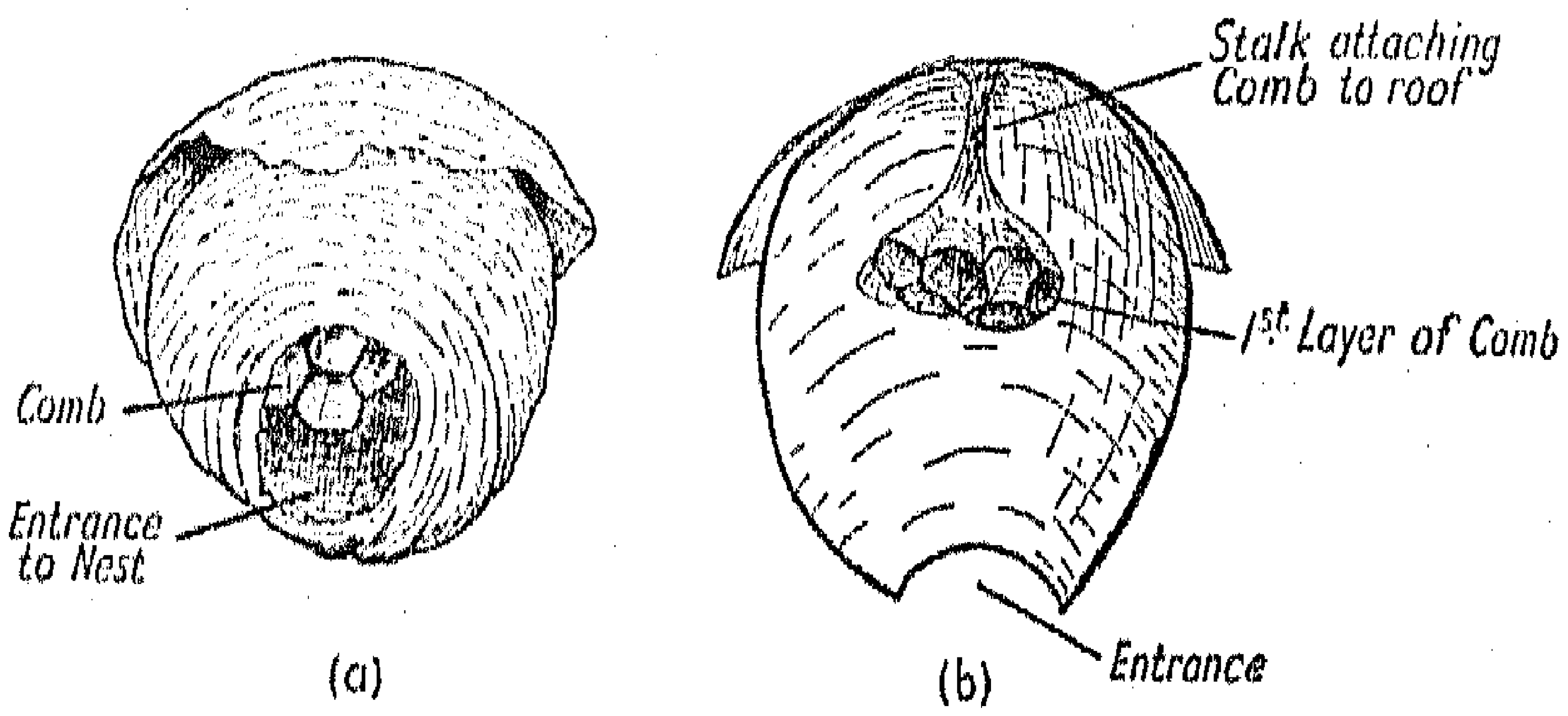


Fig. 61.—Young nest of Common Wasp. (*a*) entire nest, seen from below. (*b*) nest with half of the wall cut away to show the manner of attachment of the comb to the roof. (Both × 1.)

These new wasps are females, like the queen, but are smaller in size and not capable of laying eggs. They are called workers. These workers now take over the task of hunting for such food as insects and sugary fruit-juices, and they also enlarge the nest by building more layers of comb under the existing ones. The queen now devotes herself entirely to egg laying, and the population of the nest rapidly increases, so that at the peak there may be as many as 5,000 wasps. Sometime in August, males and young queens are produced in the nest, and fly freely outside. Soon the young queens mate with the males (though not necessarily with males from their own nest), and go to search for suitable places to spend the winter, just as their mothers did before them. When a young queen has discovered such a place, she creeps in, tucks her wings, legs and feelers underneath her, and falls into a drowsy condition, remaining in this state until aroused by the warm days of spring.

As soon as the last young queen has left the nest, the behaviour of the remaining workers changes. They kill and eat such larvæ as remain, and break up the nest. Then they leave the nest for ever, and soon perish in the cold autumn weather. The old queen dies also in this way, so that the only wasps that survive the winter are the young queens. In this way wasps resemble bumble bees, for with them also, only the young queens survive the winter. In hive bees both the queen and a good number of workers live through the winter, although the males (the drones) are killed off by the other bees at the beginning of autumn.

The foregoing account applies to the two common species of wasps, the Common Wasp, *Vespa vulgaris* (vul-gare-is), and the German Wasp, *Vespa germanicus* (jer-man-ik-us). The life histories of the other wasps differ but little. Altogether there are seven British species belonging to the genus *Vespa.*

(1) The largest is the HORNET, *Vespa crabro*, (v. kray-bro), but this is not at all common. It is so much larger than even the queens of the other British wasps that it is impossible to mistake it. In addition the colours are orange, yellow and reddish brown, instead of black and bright yellow as in the remainder. Hornets usually nest in hollows in trees. (The Hornet is shown in Plate VII).

(2) The GERMAN WASP, *Vespa germanicus*, builds underground, and is common in houses.

(3) The COMMON WASP, *Vespa vulgaris*, also builds underground and is common in houses.

(4) The RED LEGGED WASP, *Vespa rufa* (v. roo-fa). This wasp also usually builds its nest underground. Although Red Legged Wasps are quite common, you will not often catch them in houses. The legs and parts of the abdomen are usually coloured a distinct reddish brown.

(5) The TREE WASP, *Vespa sylvestris* (sil-ves-tris), usually builds in a hollow tree, or, according to some naturalists, the nest is built hanging from a branch.

(6) The NORWEGIAN WASP, *Vespa norvegica* (nawr-vej-ik-a), builds its nest hanging from a branch of a bush or low tree, fully exposed to view (Plate III).

(7) The WOOD WASP (*Vespa austriaca* (aws-tri-ay-ka), is peculiar in that it has no nest of its own, but is always found in the nest of the Red Legged Wasp. Workers of the Wood Wasp have never been found; specimens are either males or queens. Eggs are laid by the Wood Wasp queens in the combs of Red Legged Wasps and are cared for by the Red Legged Wasp workers until the adults emerge. In this way Wood Wasps are rather like cuckoos, and because of this resemblance, the Wood Wasp is sometimes called the Cuckoo Wasp. We shall find that the same habit occurs among the bumble bees (p. 120).

Here is a key to the British species of the genus *Vespa*. Remember that males have thirteen segments on their antennæ, and seven visible segments on the abdomen.

KEY TO THE BRITISH SPECIES OF *VESPA*

1	Insect about 2 inches long; colours brown, orange and yellow	HORNET
	Insect less than 1¼ inches long; colours black and bright yellow, sometimes with a reddish tinge	2
2	First segment of antenna entirely black	3
	First segment of antenna yellow underneath	5
3	Thorax with one pair of yellow spots on top at the hind end; abdomen and legs distinctly tinged with red	RED LEGGED WASP
	Thorax with two pairs of yellow spots on top at the hind end; abdomen and legs not, or only slightly, tinged with red	4

4	A black anchor-shaped mark (Fig. 60*b*) on the yellow of the upper lip; the yellow stripes running along the front sides of the top surface of the thorax are parallel-sided	COMMON WASP
	The yellow of the upper lip with three black marks arranged thus .˙. (or else the top mark may have the form of a short bar like this .'.); the yellow stripes along the front top edges of the thorax are thicker towards the hind end	GERMAN WASP
5	Yellow upper lip with a single black spot in the centre; a broad band of black on the second abdominal segment	6
	Yellow upper lip with three black dots arranged thus .˙.; the band of black on the second abdominal segment narrow	WOOD WASP
6	The black mark on the yellow upper lip a small dot; the broad black band on the second abdominal segment extending right across to the sides as seen from above	TREE WASP
	The black mark on the yellow upper lip is a heavy stripe; the broad black band on the second abdominal segment is narrowed suddenly near the edges	NORWEGIAN WASP

CHAPTER TWELVE

Bumble Bees and Cuckoo Bees

Bumble Bees—Life History

BUMBLE Bees (or humble bees) are a group of insects that must be familiar to everyone. The noisy buzz of their flight, and their heavy bodies, thickly clothed in hair, make them most conspicuous. There are seventeen species of bumble bees in Britain, and I shall describe in detail one of the most common, the BUFF-TAILED BUMBLE BEE, *Bombus terrestris* (bom-bus ter-res-tris); but before doing so I must tell you something of the way of life of these bees.

In most insect species there are only two kinds of individuals, males and females; but in bumble bees, as in wasps, there are three kinds: queens, males, and workers. Also, as with wasps, a number of bees live together in a common nest, and so form a colony. The queens start the nests and lay the eggs from which the rest of the colonies are derived; but the males do nothing to help with the work of the colonies, for their purpose is to fertilise the young queens in autumn. The third group, the workers, is composed of females that do not, as a rule, lay eggs. In structure, the workers closely resemble the queens, but are smaller in size. They are the bees that do the main work of the colony.

The only bumble bees to survive the winter are the young queens. These find some sheltered spot during autumn and remain there in a sleepy condition until spring. The queens of the particular bee we shall study, the Buff-tailed Bumble Bee, usually pass the winter in holes they have dug in the ground.

In early spring the young queens are aroused on warm days and take short flights, feeding on such nectar as they are able to obtain from the spring flowers. As the weather becomes warmer, the queens fly more regularly and commence to look for suitable nesting sites. The Buff-tailed Bumble Bee prefers the empty nest of a mouse or a vole. In the spring you can often see searching queens hovering over likely spots on the ground.

Having discovered a suitable place, the queen enters to inspect more closely. She may have chosen a mouse's nest. This consists of a mass of moss, grass and dead leaves, usually placed in an underground chamber. After the winter it is certain to be damp, so she first makes a little cavity in the centre, and here she settles down and gradually dries out the nest with the heat from her body.

Then she goes out and collects pollen from flowers. This she moistens with honey and makes into a ball, rather less than the size of a pea, which she places in the centre of the nest. On this pollen she lays about ten eggs and covers them over with wax, which is made in her body and given out from special glands situated on her abdomen.

To assist the development of the eggs, the queen sits on them, warming them with the heat from her body. At intervals, she leaves the nest to collect food. In order to store the honey that she makes from nectar collected from flowers, she builds, near to the entrance of the nest, a wax honey pot about the size of an acorn. After a collecting expedition, the honey she has gathered is placed in this honey pot, and during bad weather, when she cannot go out collecting, she takes sips from it as required.

In about four days, the eggs hatch into little whitish grubs (larvæ) that devour the honey-pollen paste on which the eggs were laid. From now on they are fed by the queen with a mixture of pollen and honey, which she places in the chamber where the larvæ are. As the larvæ grow bigger, the chamber which contains them is enlarged by the queen, who constantly adds to the covering of wax.

About eleven days after the eggs were laid, the larvæ are fully grown. They now spin delicate white covers called cocoons around themselves. Inside the cocoons they slowly change into the adult form and usually about the twenty-second day they bite their way out. At first they are wet and rather soft, but rapidly their tissues harden and they are now ready to help the queen.

These first bees are all workers and are much smaller than the queen. After a day or so they are ready to go outside the nest foraging for pollen and nectar. They also help in the building of new comb and in tending new larvæ.

The nest now expands quickly (Plate III). More eggs are laid by the queen and stores of pollen and honey are gathered. Extra honey pots are made, and the empty cocoons, from which the workers have emerged, are also used as store jars for honey. Pollen is stored in three or four special pollen jars made of wax.

The number of bees in the colony may increase to between 200 and 300, all of them workers except the original queen. However, as the season goes on, some eggs are laid that develop into new queens and others that become drones. These hatch out in late summer. The males and young queens usually leave the nest as soon as they can fly, and do not return. They manage to keep themselves alive on the nectar they can gather from flowers in blossom at that time, and you can often see males drowsing on the flowers of knapweed and thistles.

The young queens and the males mate together, but not usually males and queens from the same nest. The males die shortly afterwards, but the queens find for themselves suitable winter quarters. Usually they dig a little cavity in the ground in a place, such as a bank, that is likely to be well drained and does not catch the sun. This is important because it would be bad for a queen if she were to be awakened by the ground becoming warmed on one of the sunny days that sometimes occur in winter. Before they are washed away by rain, the little piles of earth the queens dig up may help you to discover their winter sleeping places.

The old nest (i.e., the old queen and workers) dies out completely in the late autumn, so that the continuance of the species during the next year depends entirely on the young queens.

Bumble Bees—Structure

The queen of the Buff-tailed Bumble Bee is a large insect, whose body may be 1 inch long and the wings 1½ inches across (Fig. 62). The body is thickly covered with hair, which for the most part is black; but at the front of the thorax is a band of deep yellow, and there is another belt of yellow across the front of the abdomen. The tail of the abdomen is yellowish, but not so yellow as the other bands, and the hairs of the tail

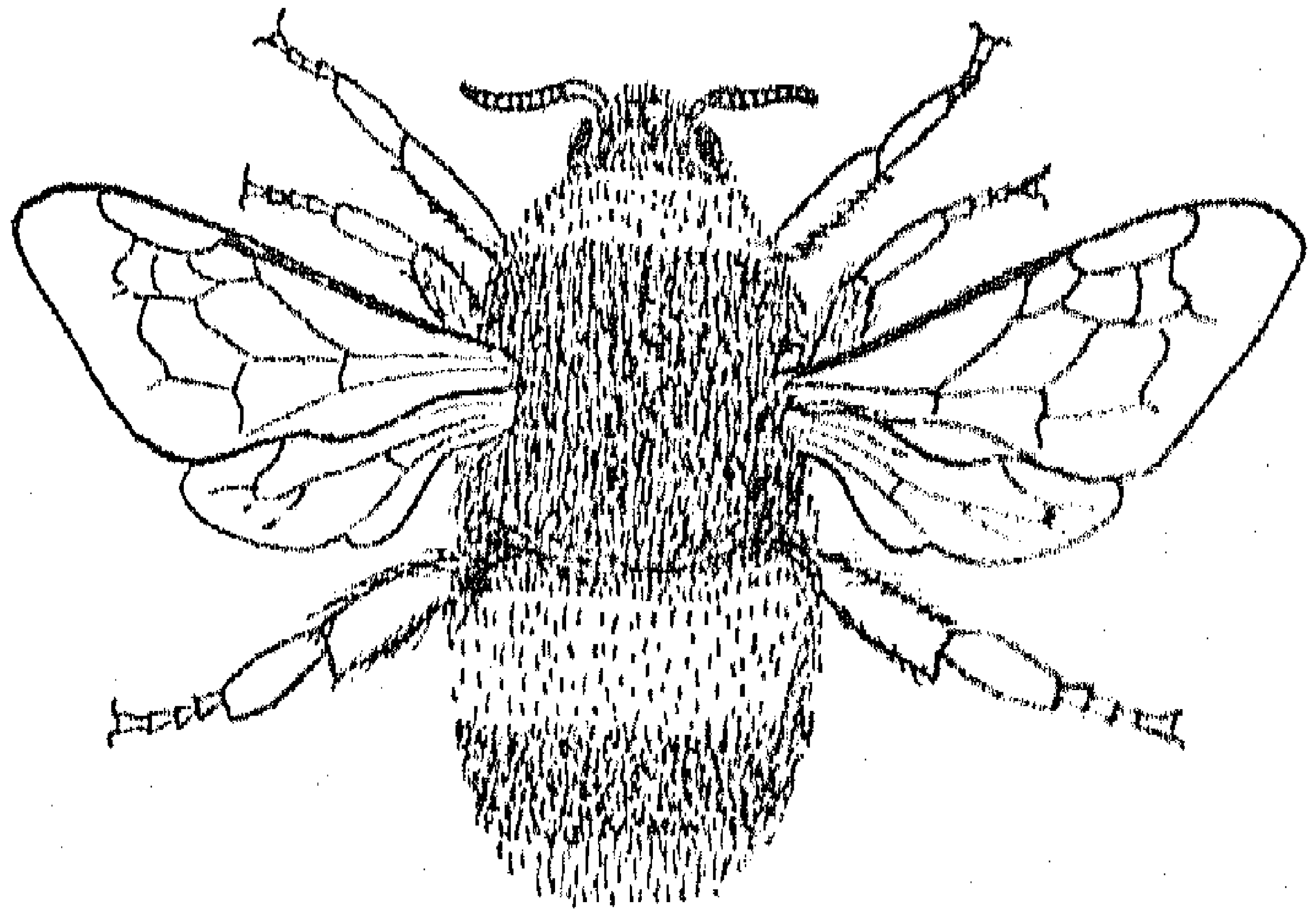


FIG. 62.—Queen of the Buff-tailed Bumble Bee (*Bombus terrestris*), ×2. A set specimen.

usually have white or cream tips. In old specimens the tail may look almost white. (Plate VII shows a Buff-tailed Bumble Bee).

On the head, the antennæ are clearly visible, sticking out of the middle of the face. You can see that each antenna is black, and consists of twelve segments. The first segment, starting from where the antenna is fixed to the head, is long; the other eleven are much smaller and are all, except the first, about the same length. At the sides of the head are the very large compound eyes; and between these, on the forehead, is a row of three simple eyes which may be somewhat hidden by hairs.

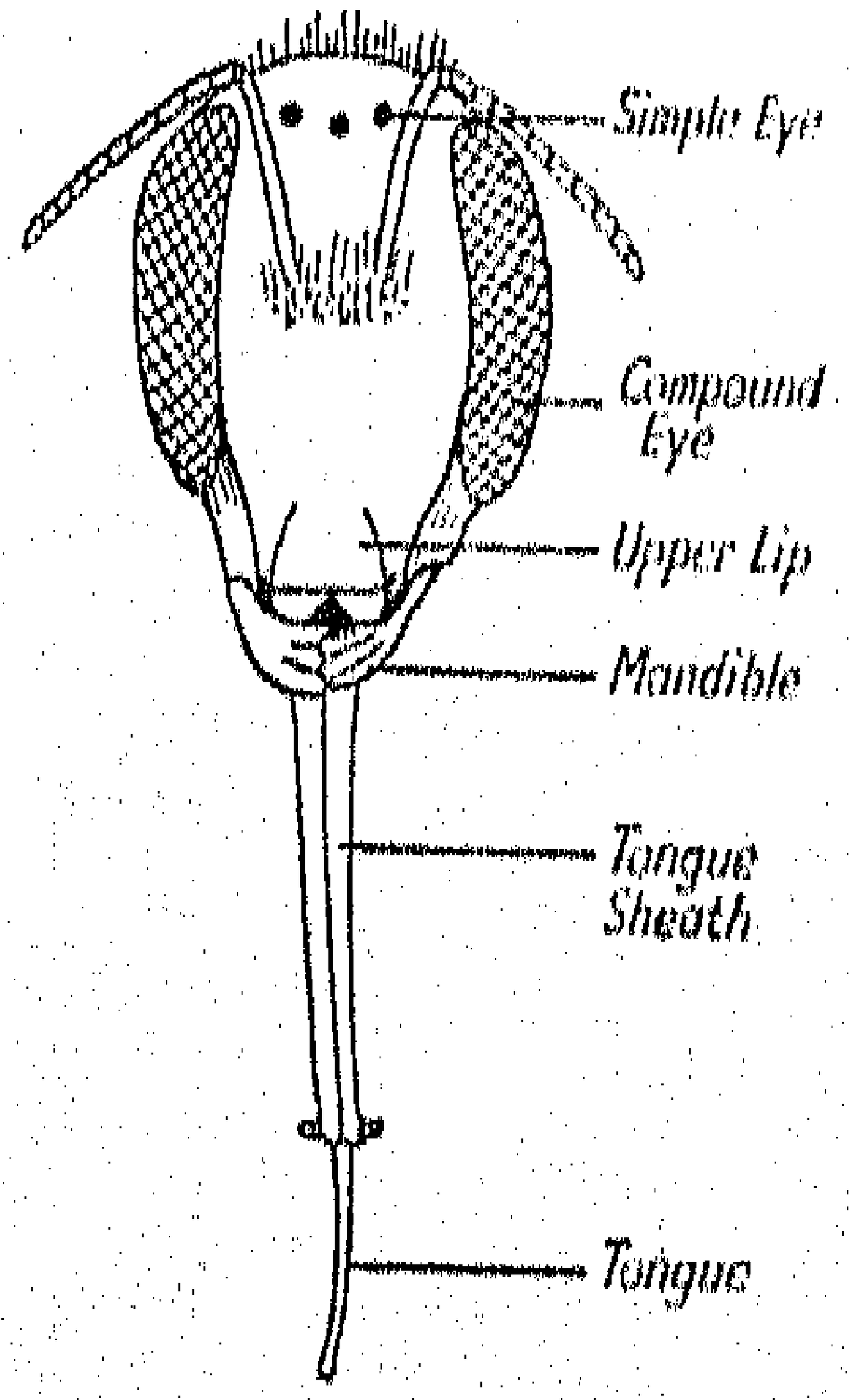


FIG. 63.—Front view of the face of a Buff-tailed Bumble Bee (*B. terrestris*) queen, ×4.

The mouth of the bee is on the underside of the head. You may not be able to see the actual opening, but the mouth parts can usually be discerned with a hand lens, especially in freshly killed specimens. In front there are two hard jaws which the bee uses for biting. Behind these, and usually sticking out a long way, is the tongue in its sheath. The tongue is quite long and rather reddish in colour, and it ends in a delicate brush with which the bee can wipe up nectar. The sheath consists of four stouter pieces. Fig. 63 should make clear the details of the head structure.

On the thorax are two pairs of wings, whose veins are arranged as shown in Fig. 64. The front wings are bigger than the hind wings, but, when the bee is flying, the two wings of each side are locked together by a curious device. Along the front edge of the hind wing is a series of little hooks, which catch on to the inturned back edge of the fore wing and fasten the wings together, so that the pair act as one wing (Fig. 65). If the wings of the bee you are examining have come apart, it is usually easy to make them lock together again by pushing the

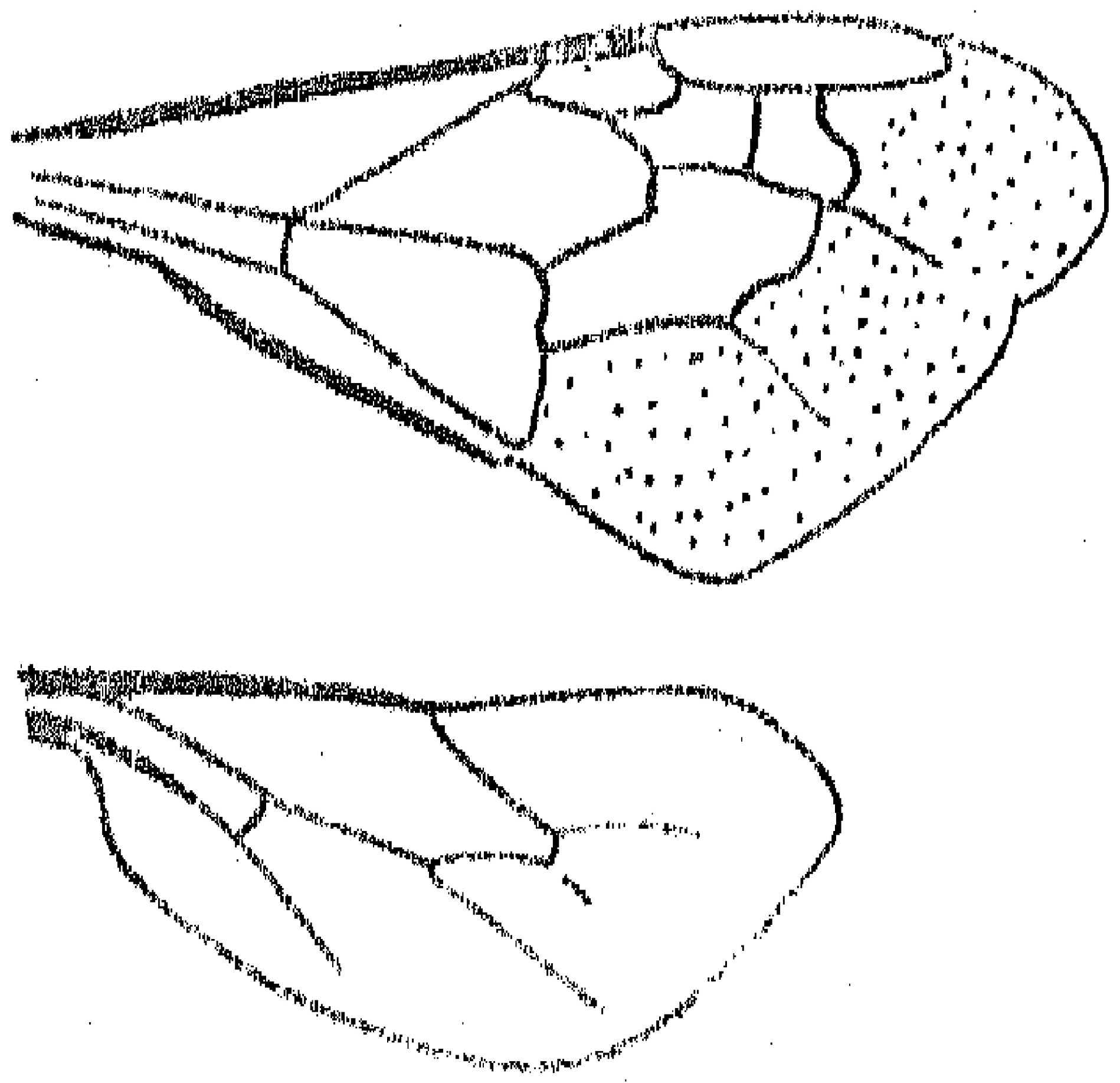


FIG. 64.—The right front wing (*above*), and the right hind wing (*below*) of the queen of the Buff-tailed Bumble Bee (*B. terrestris*), to show the vein pattern, ×4.

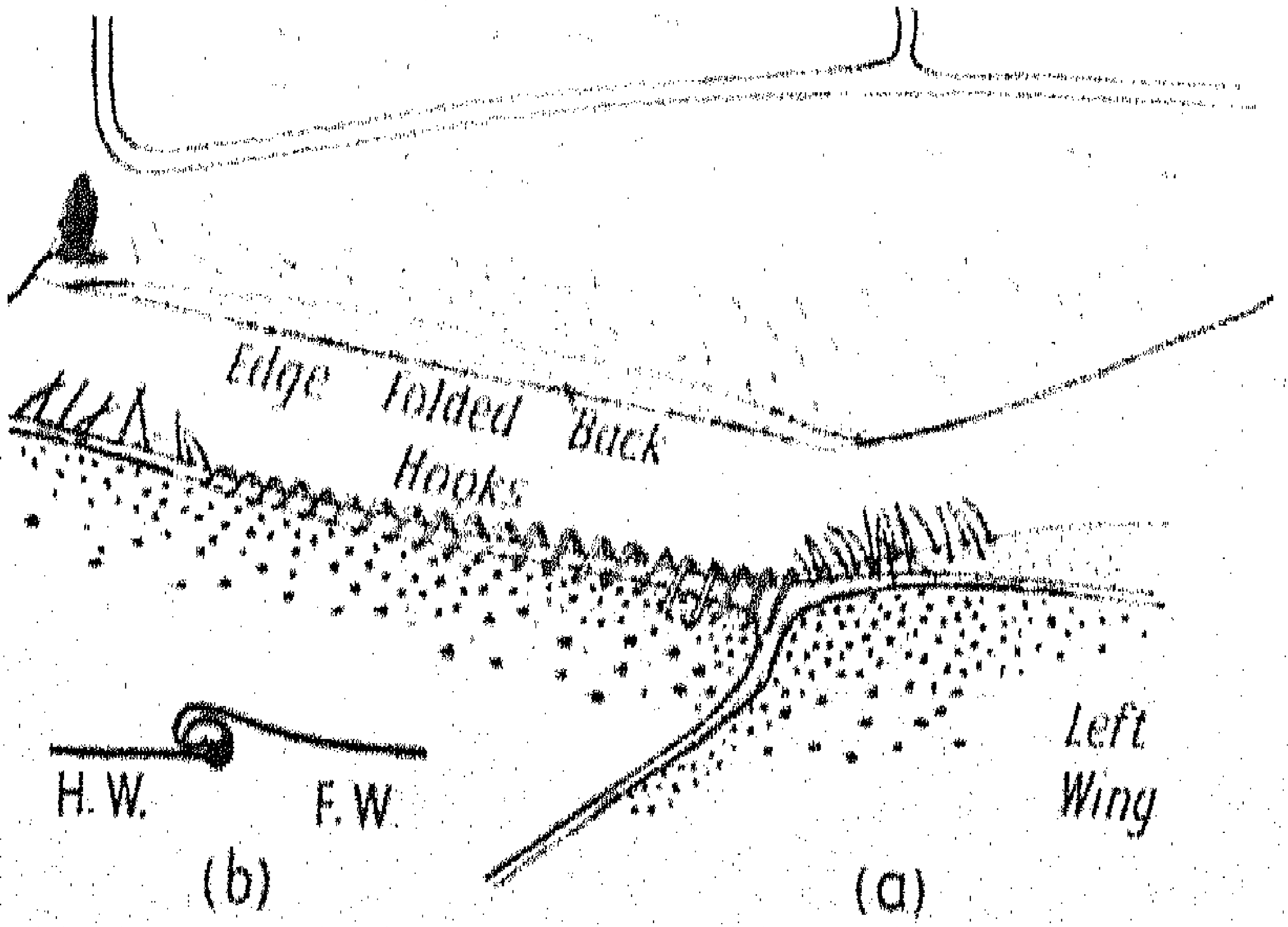


FIG. 65.—The locking device of the wings of Bumble Bees (*B. terrestris*, actually drawn). In (*a*) the hind edge of a front wing from the right side is drawn from underneath, to show the inturned edge. Below it is drawn a top view of the corresponding region of the front edge of the left hind wing, which bears twenty-one stout hooks that lock into the groove formed by the inturned edge of the fore wing. (*b*) a diagram to show the locking mechanism.

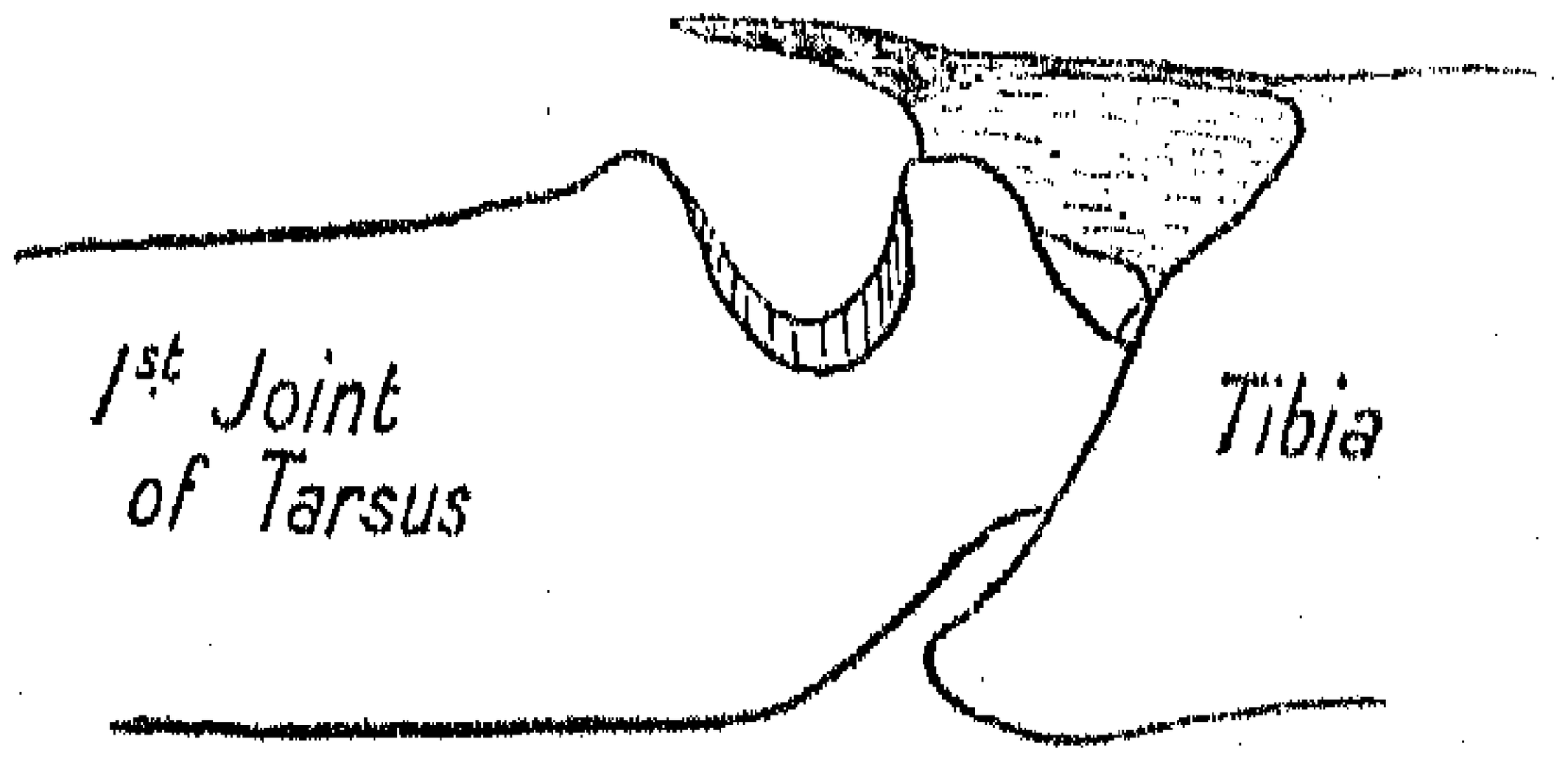


FIG. 66.—The antennal cleaning device from the front leg of a Buff-tailed Bumble Bee (*B. terrestris*), much enlarged.

hind wing up to the fore wing with a pin.

The outer portion of the fore wing, beyond where the veins finish, is rather cloudy, as you can easily see by holding the wing over a piece of white paper. In some species of bees this area is quite clear.

On the ventral surface of the thorax are the six legs; each leg consists of nine segments of which the last four are very slender (Fig. 67). The last segment of all bears a pair of claws, each claw being split into a large and small part, and between the bases of the claws you should be able to see, with a hand lens, a small hairy pad.

The five segments nearest to the tip are together called the foot or *tarsus*, and the next segment is called the *tibia*. The names of the other segments are given on Fig. 67 but are not important for our purpose. Each front leg bears a little notch on the under surface of the first segment of the tarsus, at the end which is attached to the tibia. The notch has a prominent spine placed over it (Fig. 66), and this arrangement is used to clean the antenna of that side. Antennæ are delicate sense organs, and if they become covered with dust or pollen, they cannot properly carry out their function. To keep the antennæ clean, the bee from time to time draws them through the notches and so scrapes off any unwanted matter.

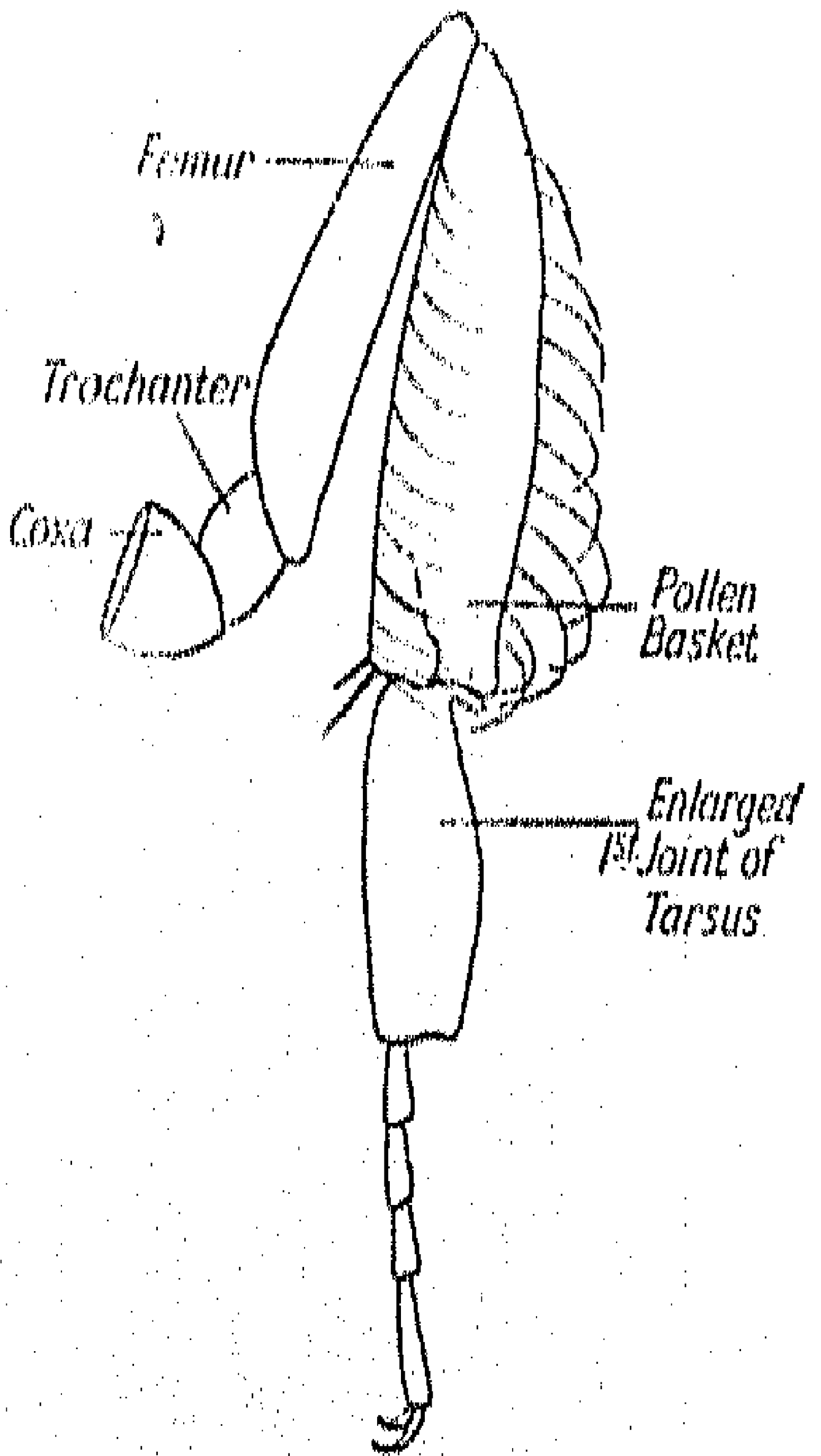


FIG. 67.—Right hind leg of a Buff-tailed Bumble Bee (*B. terrestris*), to show the pollen basket formed by stiff bristles on the outer surface of the tibia. Note the two spines at the end of the tibia (×4).

At about the same place on the second pair of legs, is a prominent spike which is used to remove pollen from the pollen baskets on the third pair of legs.

The third pair of legs is very characteristic of female bumble bees (Fig. 67). The tibia is quite smooth on its outer side and is rather hollowed out, and this hollow space is fringed with long stiff hairs which curl over the hollow and so make a kind of basket. This is the pollen basket. On the inner side of the large first segment of the tarsus are many short stiff hairs, all pointing away from the tibia. These make the pollen brush. Pollen is stored in the pollen basket by the bee when it is out collecting. You can frequently see the bright masses on the back legs of bees (both hive bees and bumble bees) as they hover in front of, or crawl into, flowers. The pollen brushes help to clean pollen off the hairy body of the bee and transfer it into the pollen basket.

On the outer edge of the tibia of each back leg, next to the tarsus, are two stout spines. I do not know what they are used for. Possibly they may help the queens in digging the hole for hibernation.

The abdomen is more thickly clothed with hair above than beneath. Viewed from below it can be seen to consist of six segments. It tapers to a point at the tail, in which the sting is concealed. In a freshly killed bee, the sting can be made to come out by gently squeezing the abdomen. It is quite unpleasant to be stung by a bumble bee; but these insects are not vicious and never attack without considerable provocation.

The workers are considerably smaller than the queens, being little more than ½ inch long, with a wing span of slightly more than 1 inch. The tail in the worker of the Buff-tailed Bumble Bee is not so yellow as that of the queen, sometimes being almost white except for the bases of the hairs, which are yellow.

The males are very similar to the workers in colour. They can be distinguished by the absence of pollen baskets from the tibiæ of the back legs; by the presence of thirteen segments on the antennæ (workers have twelve); and by the fact that the faces of males tend to be more hairy than the faces of workers.

The other bumble bees do not differ a great deal from *Bombus terrestris* except in size and colour. The CARDER BEES have very little black on them, the body being covered for the most part with yellow or brown hairs. These Carder Bees are bumble bees that build nests on the surface of the ground, surrounding them with a mass of woven moss or dry grass. Apart from the Cuckoo Bees (see below) there are only a few insects that you might mistake for bumble bees, e.g., the **Digging Bees**, *Andrena* (an-dree-na), that make holes in the lawn in spring, and the handsome black insect called *Anthophora pilipes* (an-tho-fore-a pil-i-pays). But careful comparison of the vein pattern of the wing with Fig. 64 should enable you to decide that these and similar insects are not bumble bees. The enlarged first torsal segments of the second pair of legs of *Anthophora* bear long tufts of hair that are very conspicuous, even in flying insects.

Cuckoo Bees

The account given earlier was of the normal life of a colony of Buff-tailed Bumble Bees. But often the colony is invaded by a strange queen, one of the cuckoo bees. The particular kind of cuckoo bee that may enter the nest of *Bombus terrestris* is called the **Vestal Cuckoo Bee**, and it looks very similar to the Buff-tailed Bumble Bee queen who is the rightful owner of the nest. The Vestal Cuckoo Bee usually finds the nest in early summer before there are many workers. She makes her way in and at first, if she is attacked by the workers, she will try to hide—although, as the skin of her body is very hard and the plates of the various segments tightly overlap, she is not in much danger of being stung. After some days she becomes bolder and ultimately fights with the rightful queen and kills her. The battle is very unequal because the *Bombus terrestris* queen is not well armoured and her sting, being straight, is not so suitable for this type of fighting as is the curved sting of the cuckoo bee.

The Vestal Cuckoo now takes charge of the nest, and begins to lay her own eggs. Meanwhile the Buff-tailed workers carry on with their duties, attending both to the larvæ hatching from eggs previously laid by their own queen, and to the children of the Vestal Cuckoo. There are no worker cuckoo bees; eggs laid by the queen hatch into either queens or males. So, in due time, batches of Vestal Cuckoo queens and males hatch out. These leave the nest, and, after mating has taken place, the males die and the queens find suitable places to pass

the winter. The old cuckoo bee queen, and the Buff-tailed workers left in the nest, die off in the early autumn.

The cuckoo bees are so called because, like the bird cuckoos, they get other species to rear their young. There are six species of cuckoo bees in England and each cuckoo closely resembles the bee whose nest it captures. It is not difficult to see how the cuckoo habit has arisen, for queens of one species of bumble bee will sometimes invade and capture the nests of closely related kinds. Thus Buff-tailed queens have been known to enter the nests of Small Earth Bumble Bees, kill the queens, and start laying eggs which have then been tended by the Small Earth workers already in the nest.

The cuckoo bees have a wing pattern very like that of the true bumble bees, but they can be distinguished by the following characters:

(1) Both male and female cuckoo bees have the tibiæ of the hind legs covered with hairs on the outer side, which is rounded. There is never any trace of a pollen basket. In true bumble bees there is a pollen basket present in queens and workers, while in males the tibiæ are flattened and practically without hairs, at least in the centre.

(2) Cuckoo bees are only thinly covered with hair on the abdomen, which is shining in appearance because the body plates show through the hair coat.

(3) The colours of cuckoo bees tend to be duller than those of bumble bees, and the wings look rather smoky when viewed over a piece of white paper.

(4) The tip of the abdomen in queen cuckoo bees is more or less incurved, and underneath the tip is a pair of ridges.

The key given below will enable you to name most of the queen and worker bumble bees you catch. It will not work for the males. The key is based on colour, and unfortunately the colours of particular specimens are liable to be different from that usual for the species to which they belong. Consequently you may occasionally get the wrong answer, or find specimens for which the key will not work at all. However, after you have collected a fair number of specimens, you should have little difficulty in naming most of them; and, if you keep them, you will have something to compare with any unusual specimen you may obtain. It is always easier to use a key successfully when you have a variety of specimens for comparison.

KEY TO THE QUEENS AND WORKERS OF BRITISH BUMBLE BEES

The queens and workers are distinguished from males by the possession of 12 segments on the antennæ (males have 13), and by the presence of a pollen basket on the hind legs. The males in general are smaller and more slender in outline. In the key the abdomen is understood to be viewed from above.

1	Tail white or *slightly* creamy	2
	Tail not white	8
2	Thorax with one yellow band	3
	Thorax with two yellow bands	4
3	Yellow abdominal band broken in the middle; insect rather round in outline	BROKEN-BELTED HUMBLE BEE
	Yellow abdominal band never broken in the middle; insect rather square in outline	SMALL EARTH HUMBLE BEE
4	Abdomen with one definite yellow band; tail not creamy	5
	Abdomen with two thin or faint yellow bands; tail often rather creamy	SHORT-HAIRED HUMBLE BEE
5	Rear yellow band of thorax only a fringe	SMALL EARTH HUMBLE BEE
	Rear yellow band of thorax well developed	6
6	Hairs fringing the pollen basket red; cheeks only ½ the length of the eyes	HEATH HUMBLE BEE
	The hairs fringing the pollen baskets black (or red at the tips only); cheeks more than ½ the length of the eyes	7
7	Thoracic bands a bright yellow, the front band broader than the rear one; rear thoracic band not quite reaching the bases of the wings	SMALL GARDEN HUMBLE BEE
	Thoracic bands a dull yellow, sometimes almost black; bands of same width	LARGE GARDEN HUMBLE BEE
8	Colour, except the tail, all black	9
	Colour not all black	10
9	Tail bright red; wings quite clear	LARGE RED-TAILED HUMBLE BEE
	Tail rather rusty red; wings with a dark band across the apex	CULLUM'S HUMBLE BEE
	Tail rather rusty red; wings with a cloudy zone beyond the veins	RED SHANKED CARDER BEE
	Tail white (or sometimes nearly black)	LARGE GARDEN HUMBLE BEE
10	No black hairs on thorax or abdomen seen from above	11
	Some black hairs present on the top of thorax or abdomen	12
11	Thorax lustrous orange brown, distinctly darker in the centre; the band of dark brown hairs on the abdomen not well marked	MOSS CARDER BEE
	Thorax yellowish or brownish, not much darker in the centre; the band of darker brown hairs on the abdomen well marked	BROWN BANDED CARDER BEE
12	Abdomen with bands of black and yellow	14
	Abdomen without bands of black and yellow	13
13	Abdomen all black, with a red tail which starts on the second segment (see note * below)	BILBERRY HUMBLE BEE
	Abdomen all yellow, with a darker band near the front end	GREAT YELLOW HUMBLE BEE
14	Thorax with a definite yellow band at the front, followed by black	15
	Thorax not as above	16
15	Tail red; abdominal yellow band often broken in the middle or else nearly black; coat rather uneven	EARLY HUMBLE BEE
	Tail a pale brownish yellow, the hairs often whitish towards the tips; abdominal band never broken in middle; coat very dense and even	BUFF-TAILED HUMBLE BEE
16	Thorax grey at the front and back, with black in between	KNAPWEED CARDER BEE
	Thorax with an orange-yellowish centre, surrounded by paler yellow; no black on the thorax	COMMON CARDER BEE

* *Note.* Occasional specimens of the EARLY HUMBLE BEE may have a black abdomen with a red tail, but this starts on the fourth segment of the abdomen, not on the second as in the BILBERRY HUMBLE BEE.

The names given in this chapter to the various bumble bees are not used in all parts of England. A list of the scientific names is appended.

BROKEN-BELTED HUMBLE BEE	*Bombus soroensis*	(so-ro-ens-is)
SMALL EARTH HUMBLE BEE	*Bombus lucorum*	(low-kawr-um)
SHORT-HAIRED HUMBLE BEE	*Bombus subterranis*	(sub-ter-rane-is)
HEATH HUMBLE BEE	*Bombus jonellus*	(jon-el-lus)
SMALL GARDEN HUMBLE BEE	*Bombus hortorum*	(hort-or-um)
LARGE GARDEN HUMBLE BEE	*Bombus ruderatus*	(rood-er-ayt-us)
LARGE RED-TAIL HUMBLE BEE	*Bombus lapidarius*	(lap-e-dare-e-us)
CULLUM'S HUMBLE BEE	*Bombus cullumanus*	(kul-low-may-nus)
RED-SHANKED CARDER BEE	*Bombus ruderarius*	(rood-e-rare-e-us)
MOSS CARDER BEE	*Bombus muscorum*	(mus-kawr-um)
BROWN-BANDED CARDER BEE	*Bombus humilis*	(hew-mil-is)
BILBERRY HUMBLE BEE	*Bombus lapponicus*	(lap-pon-ik-us)
GREAT YELLOW HUMBLE BEE	*Bombus distinguendis*	(dis-ting-gwen-dis)
EARLY HUMBLE BEE	*Bombus pratorum*	(pray-tor-um)
BUFF-TAILED HUMBLE BEE	*Bombus terrestris*	(ter-res-tris)
KNAPWEED CARDER BEE	*Bombus sylvarum*	(sil-vayr-um)
COMMON CARDER BEE	*Bombus agrorum*	(ag-raw-rum)

The cuckoo bees belong to a different genus called *Psithyrus* (si-thi-rus), and there are six species in England. Unfortunately they have no commonly accepted English names. Here is a key that will help you to distinguish the species. But remember that it is based on colour which is not a good characteristic by which to distinguish bees, so that you may come across difficult specimens.

SIMPLE KEY TO THE CUCKOO BEES

1 Tail all red — *Psithyrus rupestris*
Tail not all red — 2

2 Thorax with yellow in front and behind — 3
Thorax with yellow in front only (but sometimes there are a few yellow hairs behind) — 4

3 Tail all white — *P. barbutellus*
Tail yellow — *P. campestris*

4 Two prominent ridges on the surface underneath the tail — 5
The two ridges underneath the tail are very low, almost absent — *P. quadricolo*

5 The yellow at the sides of the white tail is a bright lemon yellow; coat short and even — *P. vestalis*
The yellow at the sides of the white tail is pale and soon fades to nearly white; coat longer and more uneven — *P. distinctus*

Names have been suggested for these cuckoo bees, and I give them below, together with the kind of bee whose nest each cuckoo captures.

P. rupestris	(ru-pest-ris)	THE HILL CUCKOO BEE—invades the nests of the Large Red-tailed Humble bee.
P. vestalis	(ves-tale-is)	THE VESTAL CUCKOO BEE—invades the nests of the Buff-tailed Humble bee.
P. barbutellus	(bar-bew-tel-lus)	BARBUT'S CUCKOO BEE—invades the nests of the Small Garden Humble bee.
P. campestris	(kam-pes-tris)	THE FIELD CUCKOO BEE—invades the nests of the Common Carder bee.
P. quadricolor	(kwod-re-kol-or)	THE FOUR COLOURED CUCKOO BEE—invades the nests of the Early Humble bee and the Heath Humble bee.
P. distinctus	(dis-tingkt-us)	THE WHITE-TAILED CUCKOO BEE—invades the nests of the Small Earth Humble bee.

CHAPTER THIRTEEN

Butterflies and Moths

BECAUSE of their large showy wings and their habit of flying in the daytime butterflies are among the most familiar insects. The Small Cabbage White Butterfly, *Pieris rapæ* (pi-ee-ris rape-ee), will be described, since it is common in both town and country districts.

The Small White Butterfly

The Small White butterfly is a typical insect. It has a hard skeleton covering its body, and the body is divided into three parts: the head, thorax and abdomen. On the thorax are carried two pairs of wings and three pairs of legs, while on the head are a pair of compound eyes and a pair of antennæ. Such a general description would serve for many other insects, but butterflies and moths can usually be identified at once, because their bodies and wings are thickly clothed with scales.

The head, thorax, abdomen, and legs of the Small White butterfly all have a dense covering of long hair-like scales, creamy-grey in colour, though often darker. The top surfaces of the thorax and abdomen are less thickly covered than the other parts, and so the black skin shows through. The wings are clothed completely in scales which are set in rows like the tiles on the roof of a house. They can just be seen under a good hand lens and are very easily rubbed off as a whitish powder.

The antennæ are fixed with their bases fairly close together on the top of the head. They are long and slender but are thickened into clubs at their tips. As is usual in insects, the antennæ are composed of numerous segments.

On the sides of the head, below the bases of the antennæ, are the large compound eyes, round in outline and greenish yellow in colour. Jutting forward from the "chin" are two hairy finger-like processes, the palps. Each palp has three

segments, of which the one at the free end is rather pointed and thinner than the other two.

Between the bases of the palps is the butterfly's tongue, or *proboscis* as it is more properly called. This is most likely to be tightly coiled like a watch spring, but in a living or freshly killed insect it can be straightened out by means of a pin and will be found to be quite long. Often, when it is being straightened, a butterfly's proboscis separates into two halves, a right and left. Each half has the shape of a hollow gutter, and so, when the two halves are brought together, as they are in life, a hollow tube is made through which the insect can suck nectar from flowers. This sucking action can be watched in living butterflies on flowers, or alternatively it is possible to feed a living butterfly by putting its tongue into a drop of sugar solution on the edge of a plate.

The wings are rather large. Their shape, as well as the pattern of their veins, is shown in Fig. 68. During flight the two wings on each side beat as one, but there is no special device to link them together such as is present in wasps and bees (p. 117). In flight, the front wing slightly overlaps the hind one which has a special area (the humeral lobe) developed to support the front wing.

When a butterfly is resting, the wings are folded together in an upright position over the back (Fig. 68*a*), although in sunshine a butterfly may spread out its wings to catch the warmth. The colour of the wings in the Small White varies a little in different specimens; but as a rule the upper surfaces are white, sometimes with a pale yellowish tinge, and more or less sprinkled with black, especially towards the body. In the female Small White the tips of the front wings usually have a triangular black smudge, below which are two prominent black spots, and often on the hind margin another black smudge running into the hinder-most black spot. The hind wings of females usually have a blackish spot just beyond the middle of the front margin.

In males the number of black spots is less. In addition to the black wing tip, there is usually only one spot on each front wing. On the front margin of the hind wing there may be a black spot, but in specimens hatched in spring from over-wintering pupæ, this may be absent.

The undersides of the hind wings in both sexes are a

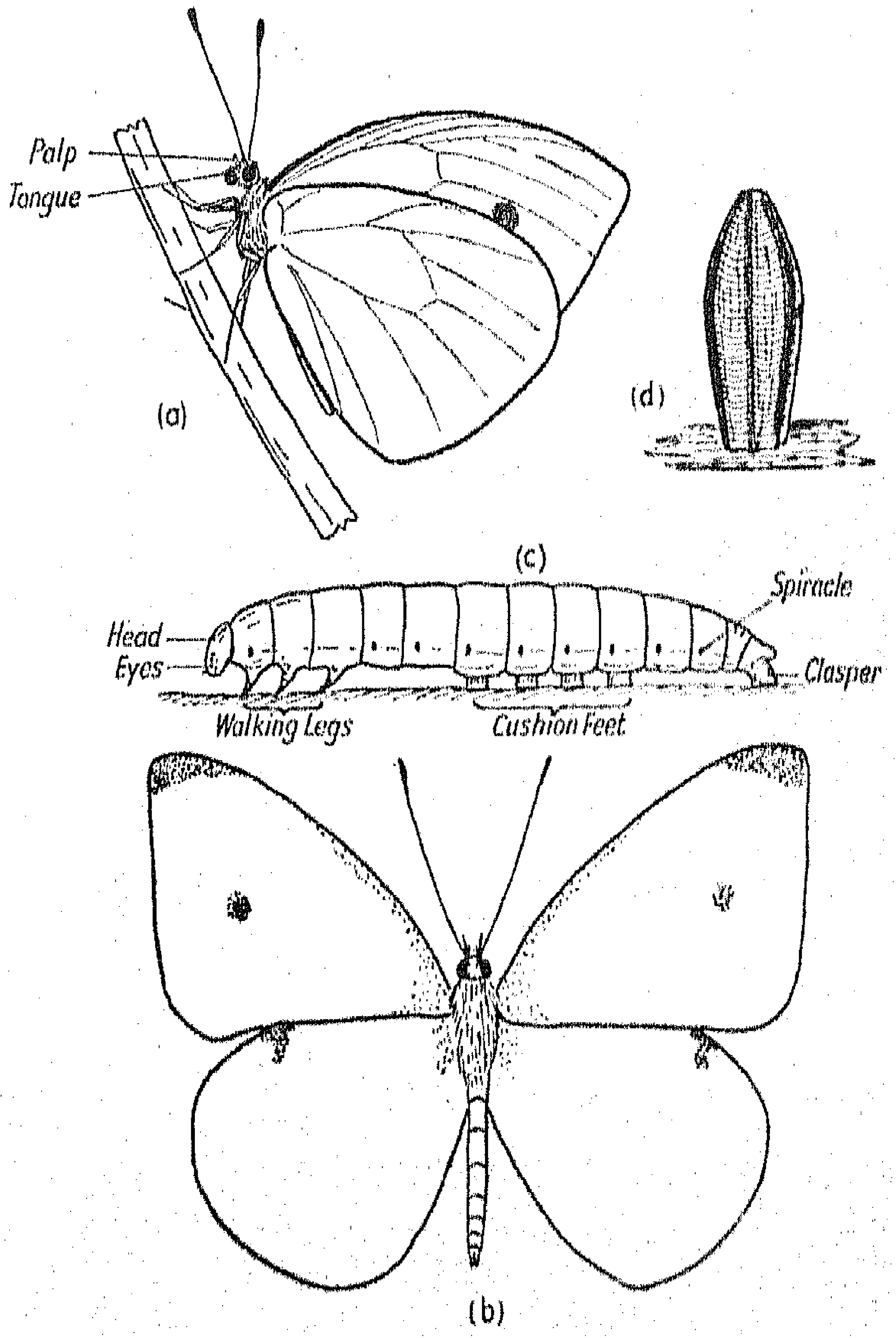


Fig. 68.—The Small Cabbage White Butterfly (*Pieris rapæ*). (*a*) in resting attitude; (*b*) male from summer brood, set specimen; (*c*) caterpillar, drawn with the hairs omitted; (*d*) egg. [(*a*), (*b*), ×1½; (*c*) ×3; (*d*) ×8.)]

distinct yellowish green sprinkled closely with black specks.

The amount of black on the Small White butterfly varies a good deal, especially with the time of the year the butterfly hatches from its pupa (see p. 133). In those insects that pass the winter inside the pupal case and hatch about May (called the spring brood), the dark markings are very much lighter in colour than they are in those that hatch out in August (the

summer brood). Sometimes black markings may be almost absent from members of the spring brood.

The six legs are rather similar to one another, and there is nothing very special to notice about them. They are rather slender and clothed in hair-like scales. The last five segments make up the foot or tarsus and the last segment of the tarsus carries a pair of claws.

The abdomen is more or less cylindrical and consists of eight visible segments which can move on one another. In those females that have not yet laid their eggs the abdomen is distinctly plump.

After a female butterfly has mated, she seeks for suitable plants on which to lay her eggs. Garden nasturtiums and the various members of the cabbage group of plants are often chosen. The eggs are laid singly and are stuck on to a leaf by means of a drop of sticky liquid. Each egg is rather skittle-shaped (Fig. 68*d*) and is a pale greenish yellow in colour. The eggs are quite visible to the naked eye, but a hand lens is required to see the fine markings on the shell. These markings consist of about eleven raised ridges running from the narrow top of the egg to the wider base. These ridges are connected to one another by raised cross ribs. The drawing makes the structure clear, but you must certainly find eggs for yourself. They are quite common and on sunny days in April and May, and again in August, if you stand quietly by a bed of nasturtiums you are quite likely to see a Small White butterfly laying her eggs. She lays them both on the top surface and the underside of leaves.

As an egg gets older, it becomes darker in colour until it is golden yellow, when a tiny caterpillar hatches from it. The time between the egg being laid and the hatching of the caterpillar varies considerably, according to the temperature: the warmer the weather the sooner the eggs hatch out. This is because living processes go on more quickly as they become warmer—though if the temperature gets too high, the living organism may be killed. Of course, in warm-blooded creatures such as man the body-temperature is kept constant, so that such animals are largely independent of the weather.

When first hatched, the caterpillar is too small to be examined comfortably. It has a hard roundish head and a soft green body. It starts to feed and grows rapidly until its tiny skin is so tightly stretched that it can grow no more. At this stage, the caterpillar moults and throws off its old skin, which splits down the back just behind the caterpillar's head. The caterpillar gradually works its way out from this split, leaving behind the old skin and the skeleton of the head. Before this takes place, however, the caterpillar has grown a new and bigger skin underneath the old, so that it is not left unprotected. For a short time the new skin is soft and moist, but it soon hardens in the air.

As the new skin is much bigger, the caterpillar can go on growing again, provided that it has food to eat. There comes a time, however, when the new skin also is too small for the increasing size of the caterpillar, which consequently has to moult again. In all, it moults four times.

After the fourth moult the caterpillar is about an inch long; its body is rather cylindrical in shape, though it is fattest at the middle and tapers gradually to each end. In colour it is green, closely resembling the green of the leaves on which it has been feeding. Along the middle of the back runs a faint yellow line, while low down on each side there is a row of yellow spots. The green body is sprinkled with very fine black dots and is covered rather thickly with short blackish hairs, each of which grows from a tiny wart-like structure.

The head of the caterpillar is quite hard and will be seen to be made up of several plates fitting tightly together. Rather low down on each side of the head are the eyes. They are simple eyes, each consisting of a single lens and there are six of them on each side of the face, arranged as shown in Fig. 68*c*.

The two jaws, with which the caterpillar chews the leaves it eats, are situated at the front and bottom of the face and the mouth is behind them. The jaws are very strong and have jagged edges which make it easier for them to cut leaves. They are most easily seen in the living caterpillar when it is feeding.

The caterpillar's antennæ are very small and consist of three segments. They are placed, one on each side, under the "chin" just below the lowest eyes.

Underneath the head, in the middle of the lower lip, is the opening of the silk glands which all caterpillars possess, but it is too small to be easily seen. On each side of this you may be able to make out two tiny palps, short finger-like processes consisting of three segments and looking not unlike the antennæ.

The body of the caterpillar has thirteen segments, but the last two are rather small. The joints between them can best be seen from underneath the caterpillar.

The first three segments constitute the thorax. Each of these segments carries a pair of short legs, and each leg has five segments and ends in a short curved claw.

The remaining ten segments make up the abdomen. Of these abdominal segments, segments 3, 4, 5, and 6, carry a pair of outgrowths called cushion feet, and segment 10 a pair of similar outgrowths which, however, are called claspers. Each cushion foot is a projection from the body wall and is quite different in structure from one of the true legs. The cushion feet have no joints and do not end in a claw. Instead they end in a fleshy pad which is supplied with two rows of very tiny hooks. To see how a caterpillar uses these hooks, you must hold it upside down and watch the "soles" of the cushion feet through a fairly strong hand lens. They are best seen in large caterpillars such as those of the hawk moths (p. 138).

The spiracles, or entrances to the breathing tubes, can easily be seen in caterpillars. There is a pair of spiracles on the first segment of the thorax and on each of the first eight segments of the abdomen. The spiracles are situated on the sides of the segments, near to the middle, and are oval in shape with a distinct rim round them, though they lie more or less flush with the rest of the skin. A spiracle is not just an oval hole, however; the entrance is guarded by valves, so that all that can be seen is a narrow slit in the centre of the oval.

Hitherto, the caterpillar has done nothing but eat, and has shown no desire to leave its food plant. However, when it is fully grown its behaviour changes and it descends from its food plant to wander away over the surface of the ground until it comes to some solid structure such as a garden shed or a wall. It climbs up this, often as high as five or six feet, until it is in a suitable place to enter into the next stage of its life history. The Small White caterpillar seems to prefer to pupate, as this next process is called, under an overhanging ledge such as a window-sill or the coping stones of a wall, but, if such a site is not available, it will pupate on the vertical face of a wall. A suitable choice of situation is important to the pupa, for it is going to remain there motionless and defenceless for some weeks—perhaps all winter—and is in great danger of

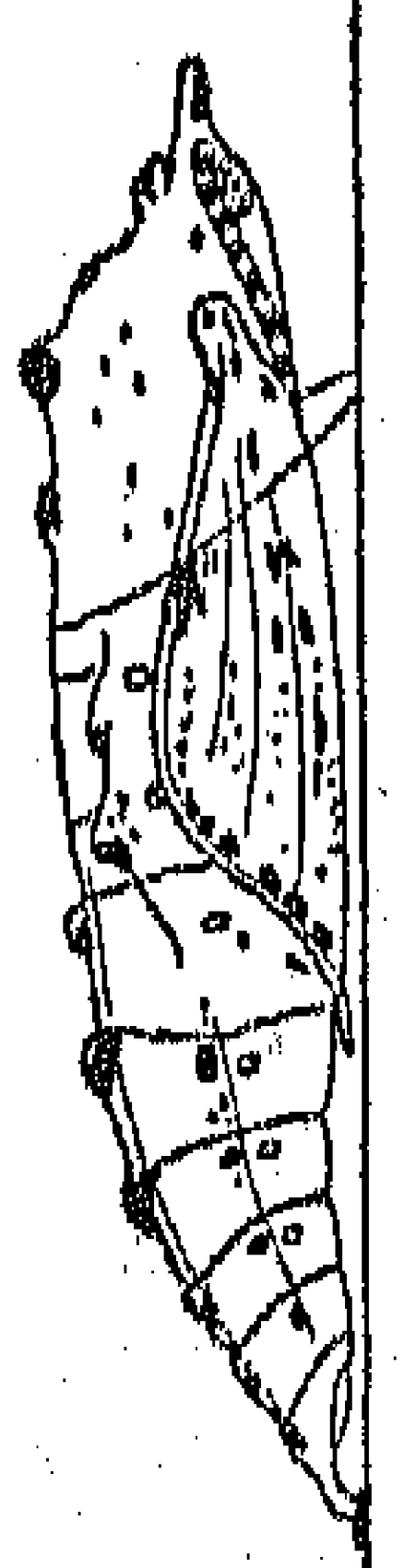


FIG. 69.—Pupa of Small White Butterfly (*P. rapæ*) in its normal position. The pad of silk to which the hind end is attached, and the supporting silken girdle, are spun by the caterpillar just before it casts its skin (×2).

being eaten by birds. Pupæ I have observed on the walls of my garden have often disappeared, and I have no doubt that they have been eaten by birds though I have never actually seen this happen.

When a caterpillar has chosen a spot, it first weaves a thin carpet of silk threads. The silk is produced from the opening under its chin already mentioned, and the caterpillar moves its head from side to side, attaching the thread to the support. In this way a thin irregular web of silk is laid down about 1 inch long and ½ inch across. When this is complete the caterpillar takes a firm grip of the silk with its hind feet and commences to spin a silken girdle to support itself. To do this it bends the head and first few segments round towards its tail and fixes a silken thread to the support near its side. Then, by moving its head, it carries the thread over its body to the other side and attaches it there. This process is repeated a number of times until the silken girdle is strong enough to satisfy the caterpillar (Fig. 69). Supported by this silken girdle, the caterpillar is now ready to turn into a pupa.

The first sign of pupation is a general darkening in colour. Shortly afterwards the caterpillar becomes shorter and fatter, and then the skin splits along the back. By vigorous shaking and wriggling, the skin is worked backwards and passes off at the hind end, leaving, in place of the original caterpillar, a peculiar structure which is at first soft and wet. This is the pupa. The pupa hangs head upwards and is supported only by the silken girdle and some tiny claws at the hind end.

The structure of a pupa is shown in Fig. 70. Its colour varies, but is usually some shade of greenish grey speckled with black. When it has dried, the pupa is covered with a hard skin, through which can be seen many of the structures of the adult butterfly. The wings are very prominent, as are the eyes, the antennæ, the tip of the tongue (which here shows very well that it is made of two parts), four of the legs, the palps, and eight abdominal segments. The spiracles on the abdominal segments can also be seen easily. They are yellow. The positions of all these various organs are shown in Fig. 70.

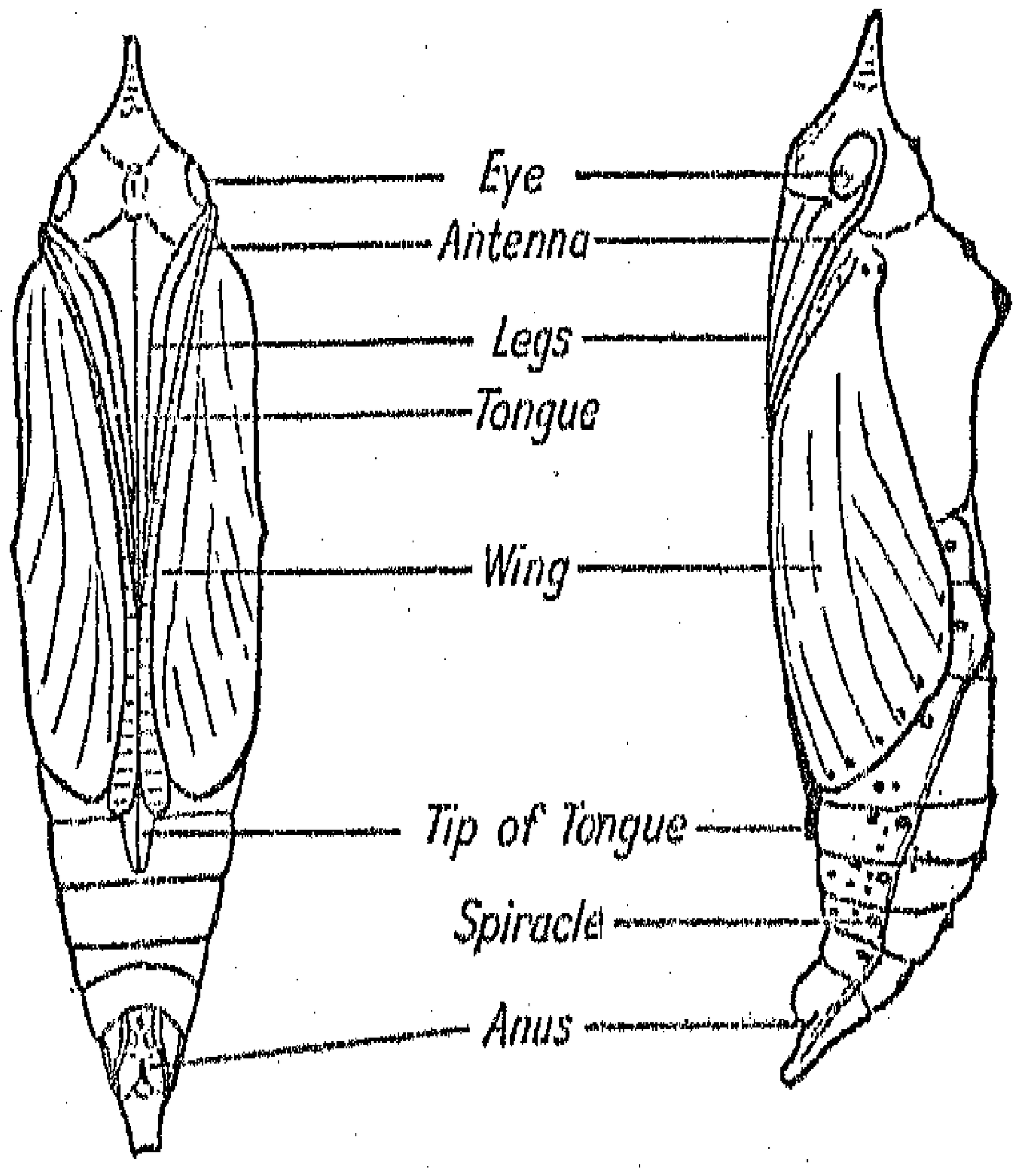


FIG. 70.—Pupa of the Small White Butterfly (*Pieris rapæ*) from below (*left*), and from the side (*right*). (Both ×2½.)

If the pupa comes from an egg laid in spring, there will emerge from it, about August, an adult insect. When this occurs, the pupal skin splits along the top surface near to the front and a rather weak looking butterfly struggles out. At first it looks rather peculiar because the wings are merely small stubs. Before they become wings, as we know them, they have to be expanded. This the butterfly does by pumping fluid through the veins so that the wings gradually expand until they are full size. After a short time they become hardened by exposure to the air and the butterfly is ready to fly away. The whole process takes an hour or two. Shortly after it comes out from the pupa, the butterfly gives off from the anus a drop of pinkish fluid. If you rear butterflies and moths, you are sure to notice this, because it dries into quite a conspicuous pink patch.

Eggs which are laid in August have a rather different history. They develop at once into caterpillars, and by the end of September or October these turn into pupæ. The pupæ remain in this state all winter and do not hatch into butterflies until the warmer days of spring, usually not until May. Eggs laid by this brood—the spring brood—will give rise to a new generation of butterflies in August—the summer brood. It has already been mentioned that the summer brood have more black upon them than the spring brood (see p. 128).

Differences Between Butterflies and Moths

Butterflies and moths are very similar to one another in structure but it is usually not difficult to distinguish them.

With a few exceptions, moths fly at dusk or during the hours of darkness before midnight, while no butterfly is on the wing after dark. Indeed, most butterflies will only fly during sunshine, and as soon as the sun goes in they settle. The antennæ of moths are rarely clubbed at the ends, though often they are feathery, especially in the males. In general, moths have thick furry bodies, while the bodies of butterflies are more slender and less densely covered with scales. Finally, as mentioned before, when butterflies are resting, they fold the wings over their backs in an upright position so that it is the undersides of the wings that show, whereas in most moths the wings are folded flat or tentlike in such a manner that the upper surfaces are visible. A few moths, e.g., the Carpet Moths frequently found on palings and tree trunks (Fig. 71) do not fold their wings at all. These points of difference hold for British butterflies and moths, but not for foreign ones. Here they are in the form of a table.

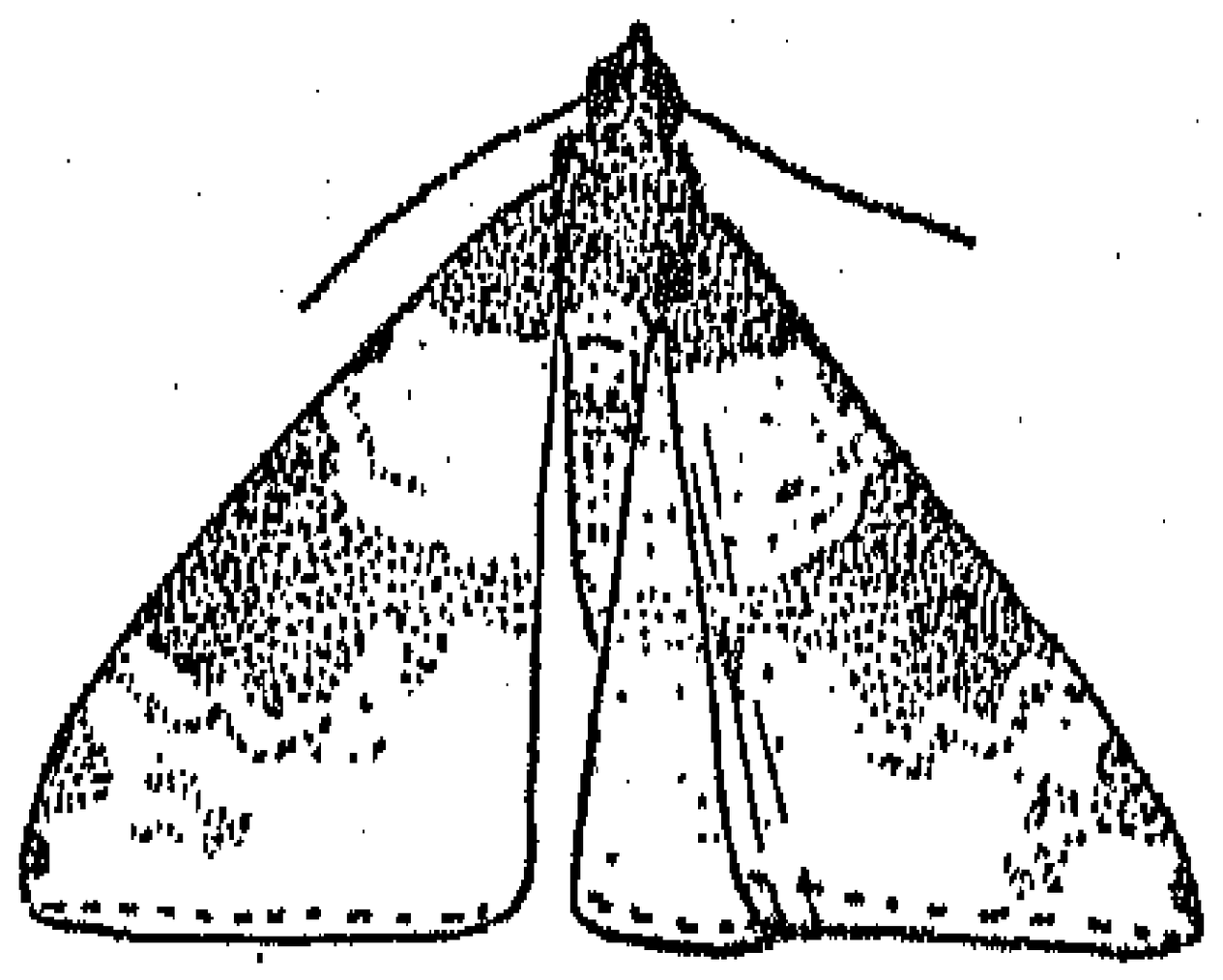


FIG. 71.—Garden Carpet Moth drawn to show how the wings are held when the moth is at rest. This is a dead specimen. In life the small portion of the right hind wing here visible would be concealed beneath the fore wing (×2).

DIFFERENCES BETWEEN BUTTERFLIES AND MOTHS

BUTTERFLIES	MOTHS
(1) Antennæ with a club	(1) Antennæ usually without club
(2) Wings folded above the body to show the undersurface	(2) Wings usually folded more or less flat over the body to show the upper surface
(3) Fly only during the daytime	(3) Fly at dusk or after nightfall (a few exceptions)
(4) Abdomen usually slender and thinly covered with scales	(4) Abdomen usually stout and thickly covered with scales
(5) Pupate above ground	(5) Pupate below ground, or if above ground they generally form a cocoon

In their adult stage butterflies and moths eat only liquid food. This is the nectar found in flowers and it is sucked up by means of the tongue which is uncoiled during the act of feeding. Butterflies seem to prefer blue flowers, and certain species (e.g., the Painted Lady) are often to be seen drinking nectar from thistles. Michaelmas daisies are also popular with the Small Tortoiseshell butterflies in autumn. Moths are especially attracted to certain white or yellowish flowers that give off scent strongly in the evening. Examples of such flowers are honeysuckle, night scented stock, and the tobacco plant often to be found growing in town gardens.

Many butterflies seem to be unable to endure the English winter, and so die out each year. The population of these species is renewed the following summer by migration from the continent. This is true of the Painted Lady, the Clouded Yellow, and possibly for some winters of that very common insect, the Large Cabbage White. Occasional specimens of the Milkweed Butterfly arrive in England, having travelled over 3,000 miles from America.

Rearing Your Own Specimens

Many people first become really keen on Nature Study through making a collection of butterflies and moths. While this is a most attractive occupation, there is a very real danger that, if too many persons become butterfly collectors, some of our rarer and more beautiful insects (e.g., the Purple Emperor, Swallow Tail, and Large Blue) may become extinct in Britain.

I want to encourage you to make a collection of insects, but, as far as rare butterflies are concerned, it is far better for you to rear your own specimens than to collect them with a net. If you manage to rear several specimens of a rare insect, do not unthinkingly liberate those specimens that you do not require for a collection. If you do, you may interfere with research work that is being carried out in connection with the distribution of butterflies. In any case, although they *might* manage to live and breed and then establish themselves in your area it is by no means certain that they will do so, for butterflies, like other living things, have their enemies; and there is usually some reason why an organism is rare.

It is not difficult to rear most butterflies and moths, but it is not possible here to give you full details of the methods best suited to individual species. If you are interested, there are plenty of good books on the rearing of butterflies and moths to be had from libraries.*

In any event you will have to obtain either the eggs or the caterpillars of the butterflies and moths you wish to rear, and find out which plants the caterpillars will eat, for each kind of caterpillar will, as a rule, feed upon only one kind of plant, or a few at the very most. The caterpillars can be bought from dealers; but it is more exciting, at least in the case of the common ones, to find out the food plants of the particular species you want and hunt for the eggs and caterpillars yourself. For instance, the food plant of the Small Tortoiseshell and Peacock butterflies is the nettle, and a search of these plants in summer will rarely fail to supply you with caterpillars of one or other of the butterflies.

When you find an unknown caterpillar feeding on a plant, as you often will, place the caterpillar in a box or a 2 lb. jam-pot with some fresh foliage, and it should continue feeding. Fresh food must be given each day and the old stuff removed, as soon as the caterpillar moves off from it. The container must not be placed in direct sunlight. Too much damp is harmful to caterpillars, so do not allow water to condense into large drops on the sides of the jam-pot.

The droppings of caterpillars are usually very moist and, if left in the breeding box, will soon grow mouldy; so they should be removed each day. To make this easier it is a help to place sawdust or dry bulb fibre in the bottom.

When the caterpillars are fully fed and, by ceasing to eat and growing shorter, seem as if they are ready to pupate, you must make provision for this.

Many moth caterpillars pupate in the soil. Other caterpillars hang suspended from twigs or pupate in the cracks of bark, and you will not know which of these things your unknown caterpillars will want to do. It is best to provide for all possibilities. So place the caterpillars in a jam-pot or large box containing about 1½ inches of moist (not wet) soil. Then push a few short twigs in the soil and lay a flat piece of bark on top. It is also necessary to cover the top of the container with a piece of cloth or other suitable material to prevent the escape of the caterpillars.

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* e.g. *The Caterpillars of the British Butterflies.* W. S. Stokoe, (Warne).

You may find that the caterpillar burrows in the soil, pupates on the bark or twigs, or on the walls of the container. In any case the container should be taken to a cool sheltered place, for preference out of doors where it is protected from rain. In time, but perhaps not until the next year, the adult insect should appear, but it must be remembered that many butterflies and moths fail to hatch from their pupæ, and that failures are frequent.

As caterpillars vary very much in shape, size, and colour, and also in the pattern of the hairs they carry, it is impossible here to attempt to describe the many forms you may see. However, one group of caterpillars, the "loopers", are quite distinctive because they have only one pair of cushion feet on the abdomen (on segment 3), in addition to the claspers at the hind end (Fig. 72). They move with a curious looping movement. These caterpillars—there are many kinds—hatch into rather dull coloured moths of the group known as the *Geometridæ* (je-o-met-rid-ee). The word means "earth measurers" and was given to them because of the way in which they move about—as if they are measuring the earth.

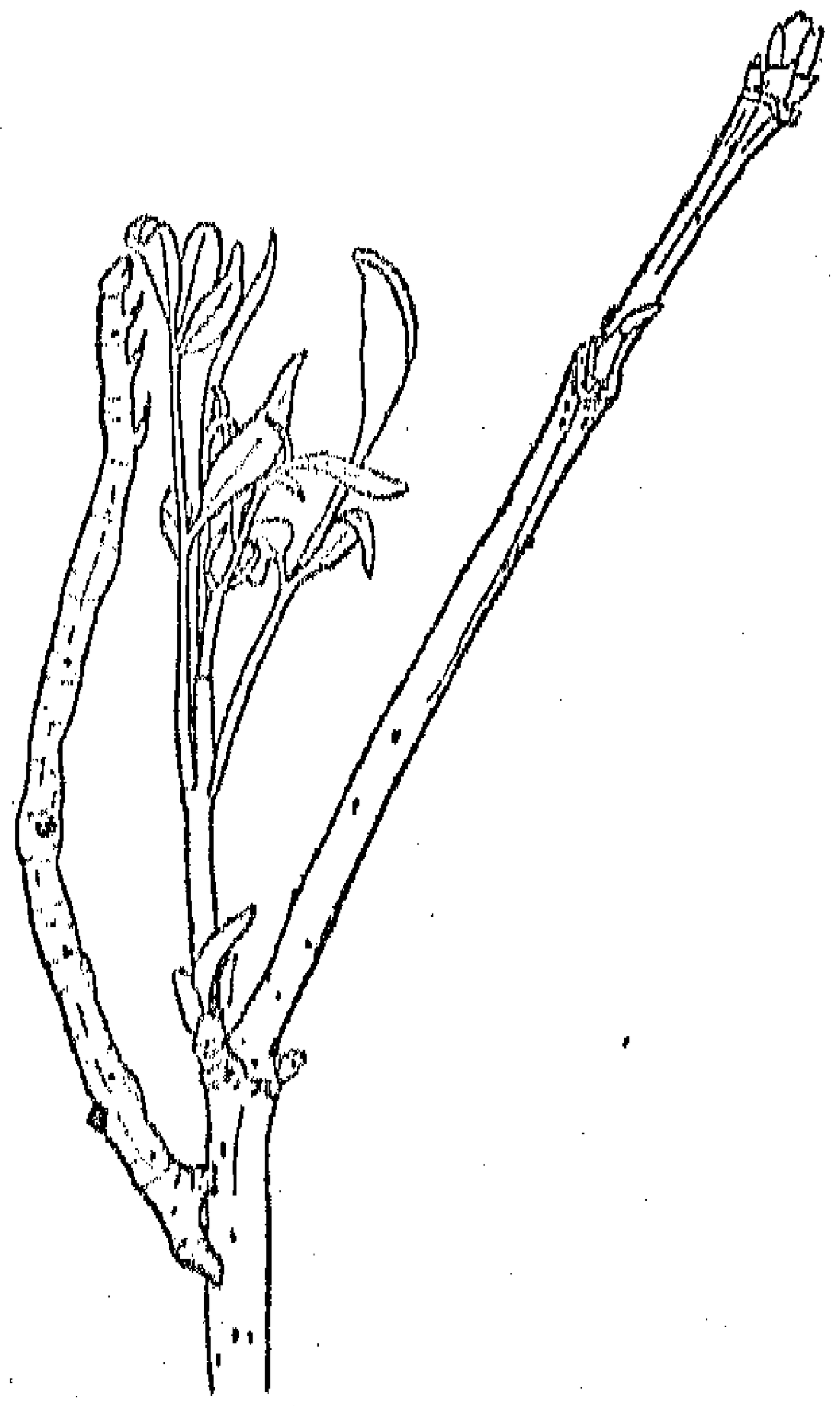


FIG. 72.—A geometrid moth caterpillar ("looper"), feeding on elderberry (× 1).

The larvæ of insects called sawflies may be mistaken for the caterpillars of butterflies and moths, which they resemble. They can be distinguished by the greater number of false legs (claspers). There is a pair of cushion-feet on the second abdominal segment, a phenomenon which is never found in the caterpillars of butterflies and moths. Moreover, these legs have no hooks on the soles of the feet (see p. 131). Finally, sawfly caterpillars have the habit of flicking their tails in an angry manner when they are disturbed.

Keep a look out for the following caterpillars, and rear them at home:

The Small Tortoiseshell Butterfly. The caterpillars are found on nettles. They are yellowish with dark specks and short hairs. There is a black line running along the centre of the back and a broad blackish stripe along each side. The body is fairly densely covered with spines which are yellowish with black tips. The black head is speckled with yellow and is hairy.

Peacock Butterfly. These caterpillars are also found on nettles. The young caterpillars are greenish, but, as they grow older, they become velvety black and sprinkled with white specks. The spines are glossy black (Fig. 170*a*).

Hawk Moth Caterpillars. The caterpillars of hawk moths grow very large. Most of them can be recognised by a curious curved spine carried on the top surface at the hind end of the body. Several of the hawk moth caterpillars have a series of oblique stripes across the body (Fig. 73). Privet Hawk, Eyed Hawk (which feeds on apples), Lime Hawk, and Poplar Hawk are all fairly common in many towns. In addition to these, at Beckenham in the Greater London area, I have caught a Death's Head Hawk Moth and a Silver-striped Hawk Moth.

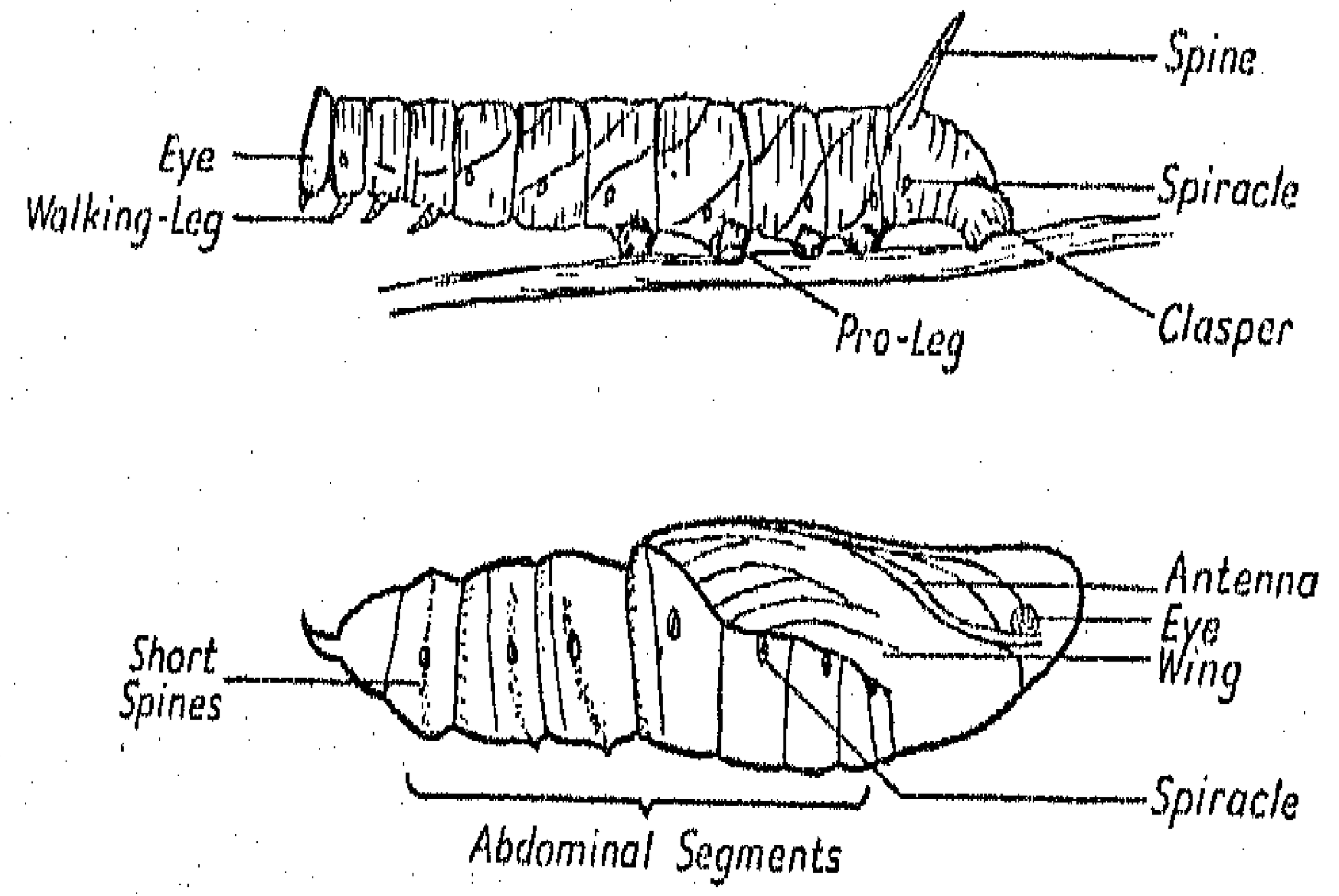


FIG. 73.—*Above:* immature Poplar Hawk Moth caterpillar. *Below:* pupa of Small Elephant Hawk Moth—a dead specimen with the abdominal segments somewhat extended (×1½).

If you intend to preserve specimens of moths and butterflies, it is usual to set them as shown in Fig. 74. The insect must first be pinned through the middle of the thorax with a special insect pin. Ordinary pins are too thick. The pin is then pushed into the centre of the groove in a suitable setting board (see p. 8) and the wings of the insect spread out sideways, so that the hind margins of the front wings are at right angles to the body. The hind wings are arranged so that their front edges lie just under the hind edges of the front wings. The wings are held in position by strips of cardboard fastened with pins. It is not always easy to bring the wings into position without rubbing off the scales, but it is possible to move the wings by pushing them near the base with the *blunt* end of a darning needle. The needle should push against one of the bigger veins.

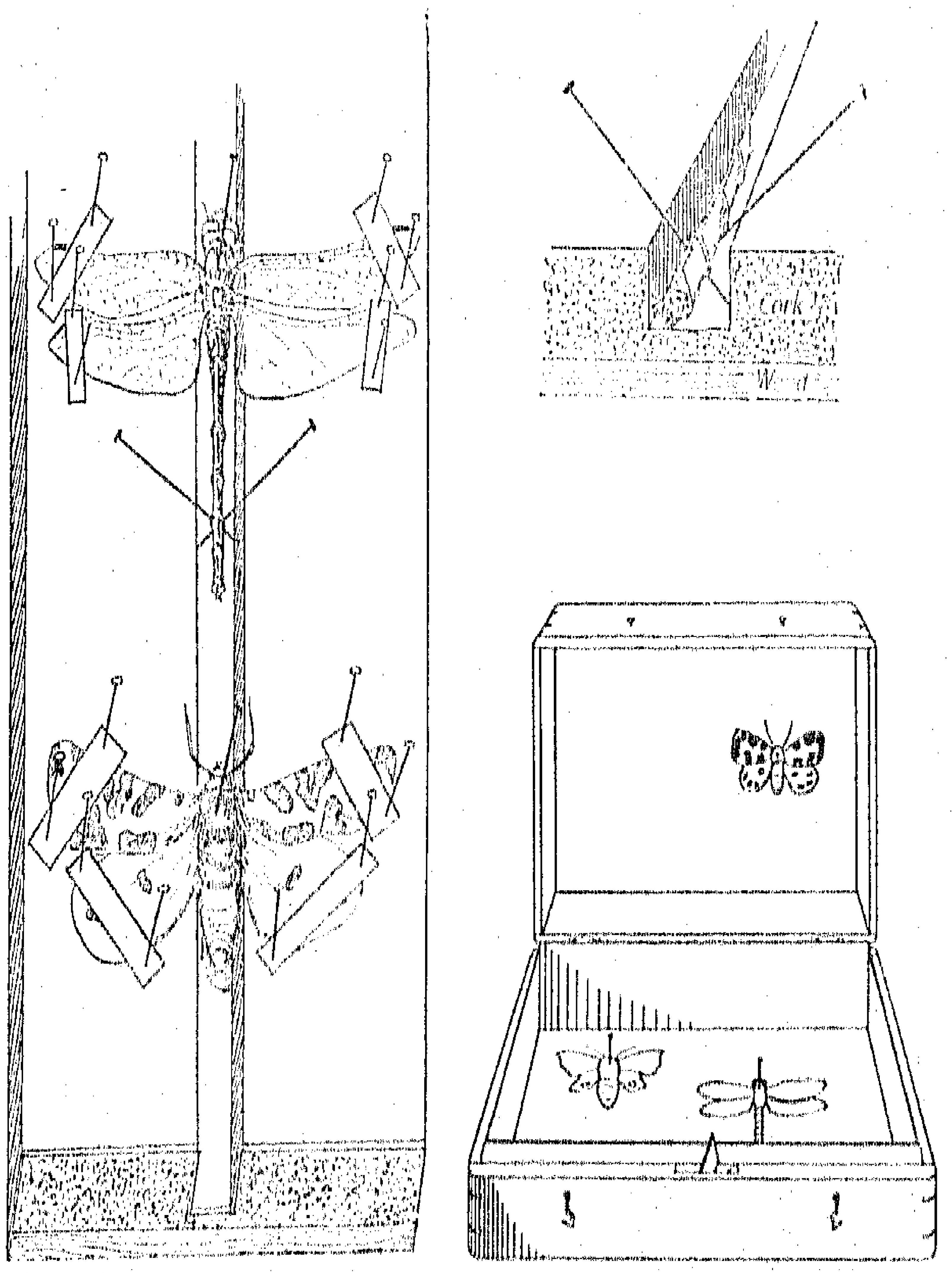


FIG. 74.—*Left:* Setting Board with two set insects (see also Fig. 4). *Top right:* method of supporting an insect's abdomen with two pins. *Bottom right:* an insect store box. Note the camphor cell built into the centre of the bottom part.

In summer the specimens will dry on the setting board in about four days. They must then be transferred to a box which will have to be lined with cork sheet (e.g., an old table mat). Special cork lined boxes called store boxes can be purchased (Fig. 74).

CHAPTER FOURTEEN

Beetles

THERE are more than 3,000 different species of beetles in Britain, and they range in size from the large Stag Beetle (2½ inches long) to tiny creatures no bigger than one of the full stops in this book.

Although there are so many different kinds, it is not as a rule difficult to recognise a beetle. Beetles have two pairs of wings, but those of the first pair are hardened into plates called *elytra* (el-it-ra). These plates fit over the abdomen and completely cover the second pair, which have the normal insect wing structure (i.e., they consist of sheets of membrane strengthened with veins). Other insects besides beetles have the front wings hardened; but in beetles the two elytra meet edge to edge in the mid-line of the body, so that the join between them runs down the centre line of the insect (Fig. 75).

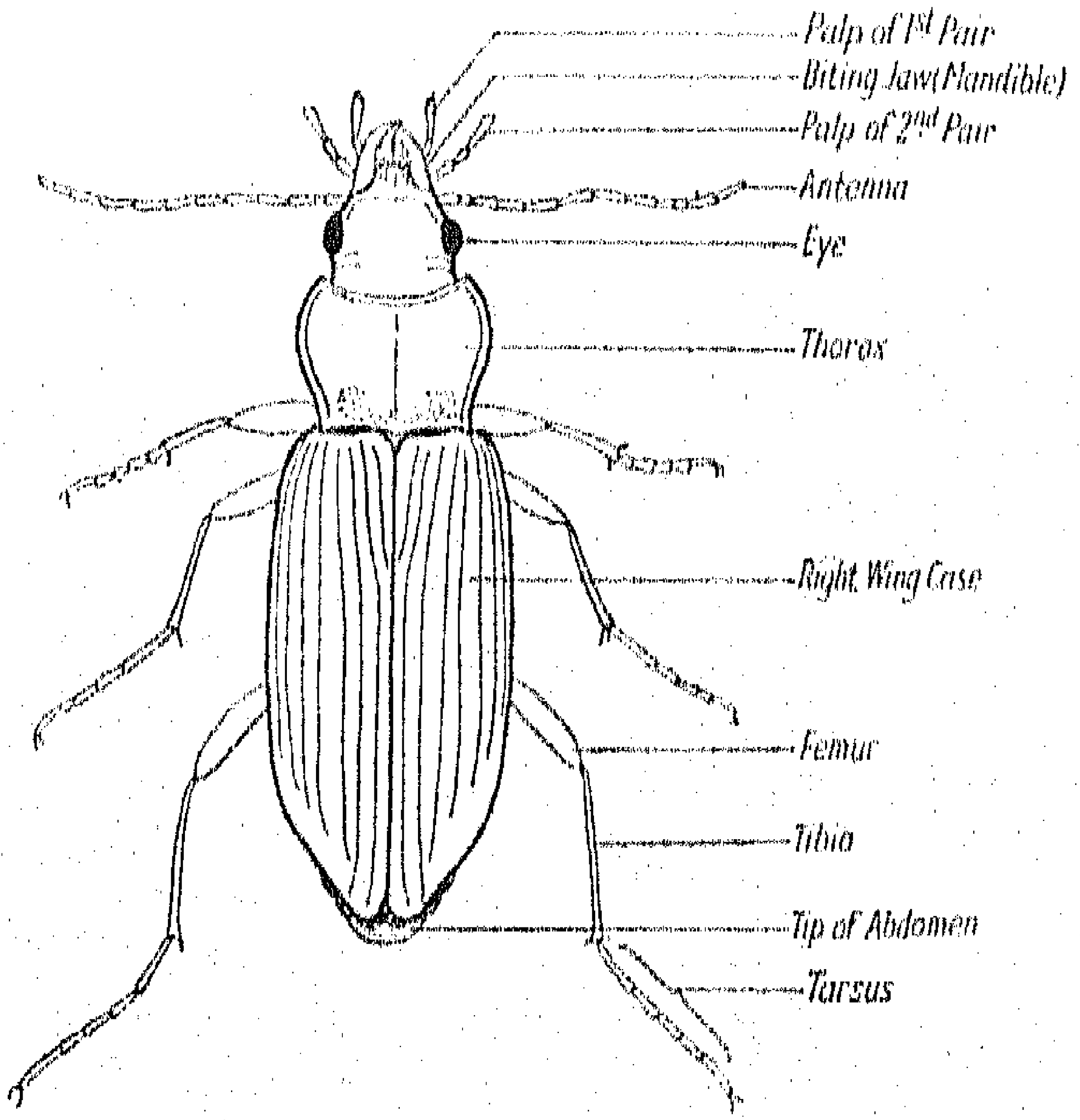


FIG. 75.—A typical beetle (enlarged).

In some beetles the second pair of wings is very small or may even be absent, as in the Bloody Nose beetle. In most beetles the elytra reach back from the thorax almost or quite to the tip of the abdomen, so that there is nothing of the abdomen (or at most the tip) to be seen when the insect is viewed from above.

There is one group of beetles, the *Brachelytra* (brak-el-it-tra) or Short Elytra group, in which the elytra are so short that several abdominal segments are exposed to view (Fig. 77). These beetles look something like Earwigs, but of course do not have a pair of pincers at the tail end.

Ground Beetles

It will be more useful to give you an account of beetles in general rather than to describe in detail any one particular species. The black beetles you find so frequently running across the garden path, or on pavements near waste ground in towns, will serve excellently for you to distinguish the main features of beetle structure. These beetles belong to a group known as the Ground Beetles (Fig. 75).

The body of a beetle is distinctly divided into head, thorax, and abdomen; but a peculiarity of beetle structure is the way in which the various plates of chitin fit closely together. Certain beetles are probably the most securely "armour-plated" of all insects.

On the head of every ground beetle will be found a pair of thread-like antennæ consisting of eleven segments. The antennæ of other beetles vary somewhat (Fig. 76). At the sides of the mouth is a pair of strong biting jaws which are often provided with sharp tooth-like points. If a specimen has its jaws closed, they can easily be forced open with a pin. Behind these jaws are other jaws, and amongst them you will have no difficulty in seeing the palps, which look like small antennæ of two or three segments.

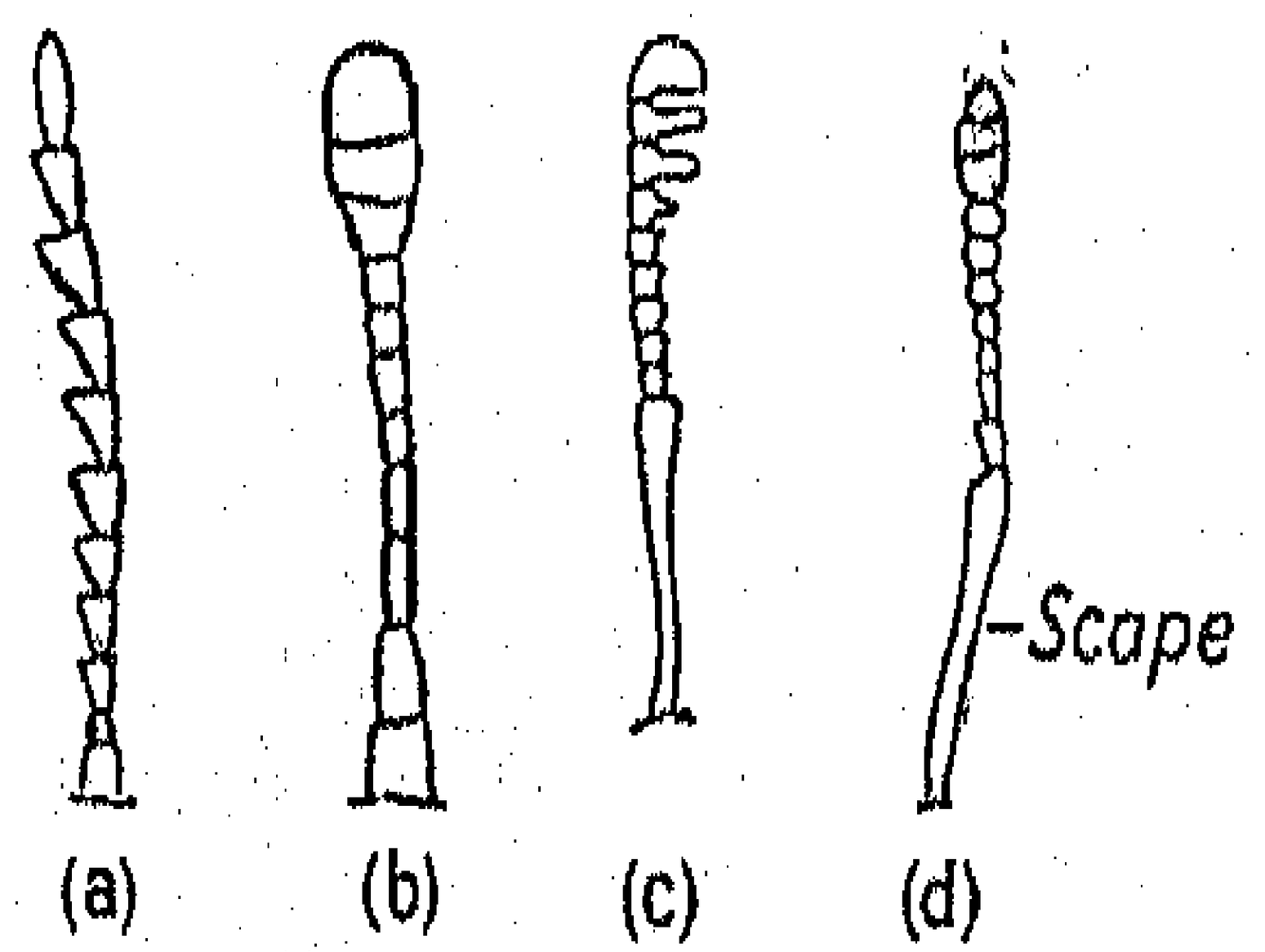


Fig. 76.—Some types of beetle antennæ. (*a*) saw-like antenna characteristic of Click Bettles; (*b*) clubbed antenna of Ladybird Beetle; (*c*) lamellicorn antenna (of Small Stag Beetle); (*d*) antenna with a scape (long first segment), as possessed by most weevils. (All enlarged.)

The large compound eyes are placed just behind the antennæ. They vary somewhat in shape in different beetles but are always present. There is no sign of any simple eyes.

There is nothing special to be said about the thorax, except that while the front part bearing the first pair of legs is freely movable, the part bearing the second and third pairs of legs is firmly joined to the abdomen and not movable.

The legs are quite typical insect legs. They are long and slender, a shape that makes it easy for these beetles to move actively over the ground. The feet (or tarsi) have five segments (but may have fewer in other kinds of beetles) and the last segment bears a pair of curved claws. In other beetles the legs may be altered in various ways to serve special purposes, such as digging or swimming.

The wings have already been mentioned. During flight the hard elytra are held out at an angle from the body rather like the wings of a glider. They remain motionless but leave room for the hind wings to vibrate up and down. After flight, the hind wings are drawn back out of sight under the elytra, a process you should be able to observe fairly easily in Lady Bird beetles on a sunny day when these fly freely.

The elytra may be variously coloured. Metallic green, yellow, bronze, and purple tints are all quite common, as are shades of bright red, though perhaps black is the most usual colour. In addition to being coloured, the elytra usually show various markings, generally in the form of ridges or rows of raised dots, sometimes with depressions or dents. There may also be rows of shallow pits or other markings on the thorax. The markings are usually different in different species and are a help in identifying specimens, but that is a task beyond us here.

Beetles are often clothed in short bristle-like hairs which sometimes give the insects an orange or reddish yellow appearance. Sometimes these hairs are so short that they are visible only through a strong hand lens.

The abdomen can normally be seen only from beneath. It will usually be found to have five or six segments, which do not move much on one another.

Beetles lay eggs more or less oval in shape, and from them, in due time, hatch the beetle larvæ. These have a hard head and a rather soft body, are usually white in colour, and have a few rather long hairs on the body. As a rule there are legs present on the first three segments of the body (the thorax) and the head has a number of simple eyes. The easiest beetle larvæ to obtain are those of Lady Birds. In summer, they are to be found in fair numbers on rose trees that are attacked by green-fly (see p. 161). Other beetle larvæ can be obtained from rotten wood, or from the caps of such fungi as mushrooms and bracket fungi, which will often be found to be riddled with small holes made by the beetle larvæ boring their way about. If you find a fungus whose cap is full of "maggots", keep it in a jam-pot with a muslin cover. Generally you will find a number of beetles in the pot after a few weeks. If the fungus is very sloppy, place a few balls of screwed-up newspaper in the pot.

Some Distinctive Groups of Beetles

The beetles form an order of the insect class called the *Coleoptera* (ko-le-op-ter-a). British beetles are divided into many smaller groups, but it is quite impossible in the limits of this book to give you a key to the name of each particular species of beetle that you may catch. A few of the groups are very distinctive and I will give you their principal characteristics, so that you will be able to recognise some at least of the main groups.

The **Ground Beetles** have already been described, but here are their main characters again. They are active, running beetles with long slender legs and each foot (tarsus) has five segments. They have threadlike antennæ of eleven segments, and conspicuous palps. They are frequently found under stones and among moss. Belonging to this group is the Green Tiger Beetle which is frequent on the sandy heaths of the south of England, and the Violet Ground Beetle (Plate IV), which may be found running about or in holes in rotten tree stumps that have become filled with leaf mould and decaying wood.

The **Brachelytra**: In these beetles the elytra are very short so that several of the abdominal segments at the hind end are left uncovered. These uncovered segments form a sort of tail which is quite soft and flexible in some beetles, and can be curled over the back. The Devil's Coach Horse (Fig. 77) is one of the largest and is not uncommon. It is a dull black, and has the habit, when alarmed, of opening its jaws and raising the tail over its back in a threatening manner. Many of the smaller *Brachelytra* are black but have the elytra coloured red. These bettles fly about freely on hot days. Several species are commonly found under dead birds and other animals left lying about in the open, and others in dung.

Many of the *Brachelytra* are to be found as guests in ants' nests. To find these, you must dig up ants' nests with a spade and throw them on to a white sheet or piece of paper. You will then easily see any beetles present by their active movements.

Weevils: These form a large group of beetles. The majority of the members, though for the most part rather small, are easily recognised because the head is drawn out into a rather long and usually slender beak or snout (Fig. 77). The antennæ are near the end of the snout, and usually terminate in a distinct club. They also have a long first segment which creates a sharp elbow where it is attached to the other segments (Fig. 76*d*).

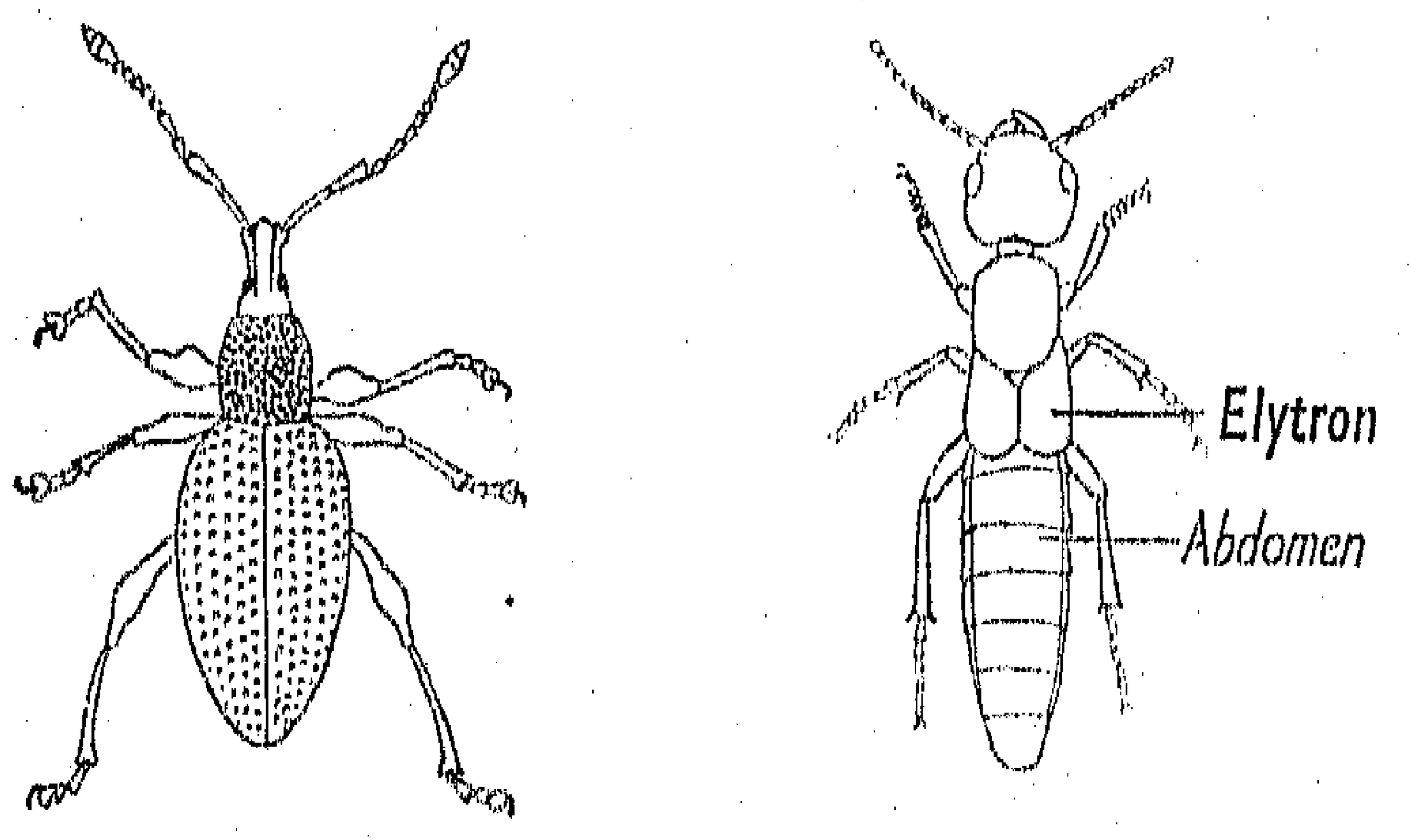


FIG. 77.—*Left:* a characteristic weevil, *Otiorrhinus sulcatus*, a frequent garden pest (×2½). *Right:* a brachelytra beetle, *Staphylinus olens* (Devil's Coach Horse), ×1.

Weevils live by sucking plant juices. Their mouth and mouth parts are placed at the end of the long snout. The maggots frequently found in peas and in acorns are the maggots of weevils.

Lamellicorns (la-mel-e-korns): These beetles can be distinguished from others because the end few segments of their feelers have the form of flat plates which are joined together somewhat like the pages of a book. These plates can open and shut. The tarsi of *Lamellicorns* have each five segments.

The Stag Beetle, our largest British beetle, is a lamellicorn. In the south of England it is quite common during summer. The males have enormous mandibles which are capable of giving your finger quite a painful nip). In the females the mandibles are much smaller but can give an even more unpleasant nip than those of the males. Stag Beetles occur at many places all over England, even in the suburbs of London where they are abundant in some years. When they fly, as they do at dusk, they are rather terriflying, but they are easily knocked down with the hand.

Many of the **Dung Beetles** which are responsible for some of the round holes found on patches of cow-dung also belong to this group (Plate IV). Their legs are strong, with tooth-like spines that assist them to dig holes in the ground. Among the largest of this group are the Dor Beetles which fly at dusk with a heavy droning flight. There are several species and they are all black, though some have a metallic blue sheen, especially underneath. One, the Lousy Dor, is usually covered with a number of tiny pinkish grey mites that run actively over its body or cling on tightly especially below its neck. These mites are parasites that puncture the skin of the beetle and suck its juices. Similar mites are found on other beetles (e.g., the Sexton Beetles) and on some of the humble bees.

Three-Horned Dor Beetles are found on sandy commons where rabbits abound. They are smaller than the other Dor beetles and the male has three prominent spines sticking out forwards from the front end of the thorax, though the spines are absent from the females. These beetles dig holes in the sandy ground down which they push rabbit droppings whereon they lay their eggs. When the larvæ hatch, they use the dung as food. The adult beetles also feed on rabbit droppings.

Sexton Beetles: These are fairly large beetles, over half an inch long and quite sturdy. Their elytra are cut off square at the tail end and do not completely cover the abdomen. The exposed abdominal segments bend downwards and the tip of the tail so formed is rather sharply pointed. The general shape is the same for all species of this genus *Necrophorus* (ne-krof-or-us), and is given in Fig. 78. The antennæ have ten segments, of which the last four form a distinct club. The head is quite large and is freely movable on the thorax.

The Sexton beetles get their name from the habit they have of burying dead animals and birds. If you find a dead bird and lift it up, it is very likely that you will discover one or more of these beetles at work. When a Sexton beetle finds a dead creature, it gets underneath it and scoops away the soil with its powerful legs, so that gradually the corpse sinks into the ground and is soon covered completely with soil. The female Sexton beetle then lays its eggs on the corpse which serves as food for the larvæ when they hatch.

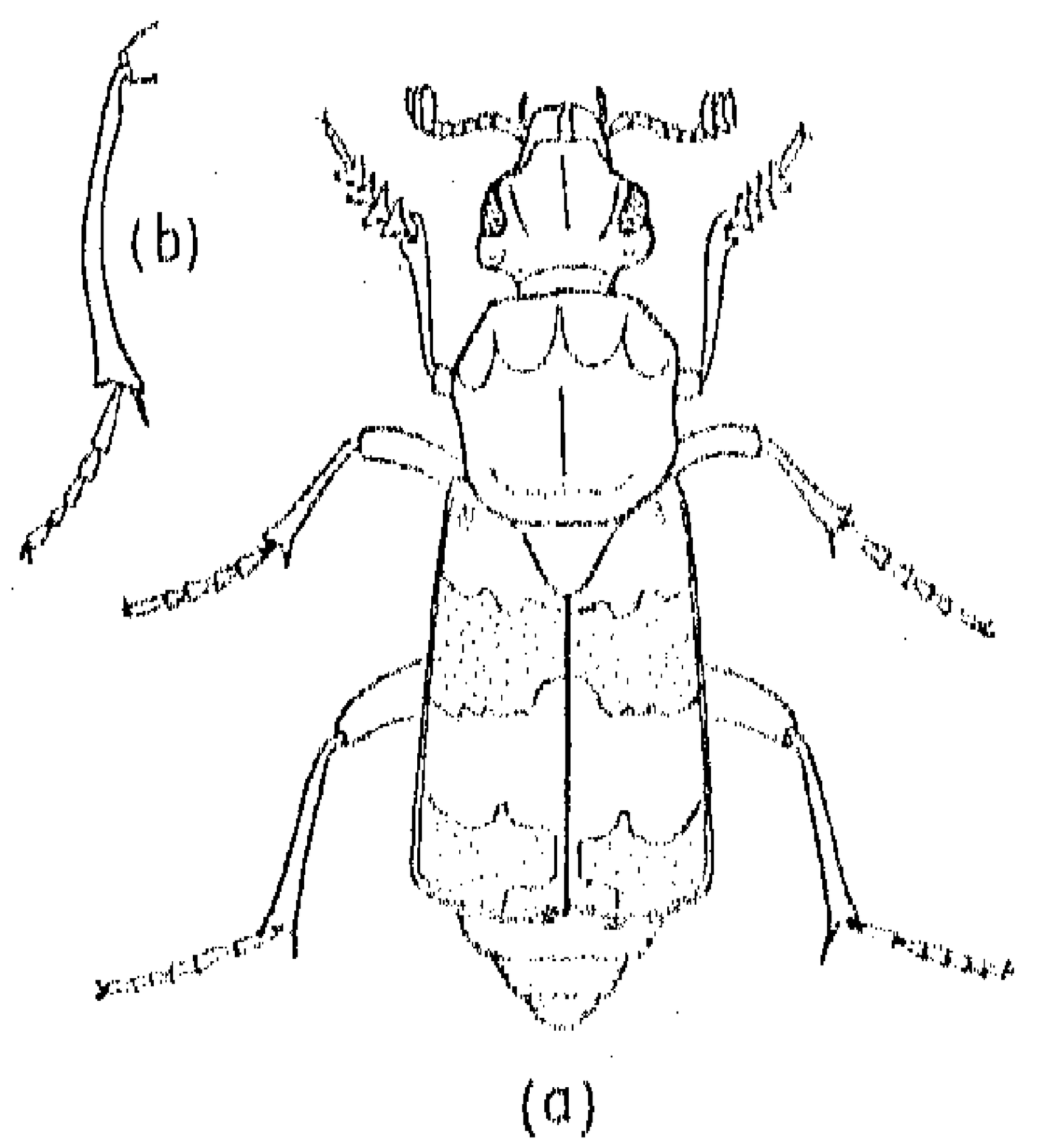


Fig. 78.—(*a*) Sexton Beetle (*Necrophorus investigator*), ×2. (*b*) left hind leg of *N. vespillo*, ×2.

These beetles are common even in large towns. I found two in June under a dead starling on a bombed site in the centre of Coventry. If you can get hold of a dead bird, or mouse, or a fowl's head, leave it in the garden in a shady place. Protect it from cats with a piece of wire netting and examine it every day. You should get some Sexton beetles in this way, and in any event you will get some of the Carrion Beetles, and those *Brachelytra* that feed on dead animals though they do not bury them.

Although Sexton beetles are most easily found under dead animals, they can fly very well and are occasionally met with elsewhere. There are seven species in the genus but two are rare and only two really common. The other three are local, i.e., found only at particular places.

The following key should enable you to identify any Sexton Beetle you may find. First check the characters to make sure that you have a Sexton Beetle. Compare your specimen with Fig. 78. (A Black Sexton Beetle is shown on Plate IV).

KEY TO THE SEXTON BEETLES

Genus *Necrophorus*

1	Elytra all black	*Necrophorus humator*
	Elytra not all black, having reddish brown or yellowish marks	2
2	The tibia of the hind legs very curved so that the insect appears bow-legged (Fig. 78*b*) when viewed from behind. Elytra parallel-sided	*N. vespillo*
	Hind legs straight	3
3	Antennæ, including the clubs, all black	*N. vespilloides*
	Clubs of antennæ reddish yellow	4
4	Thorax with yellow hairs on it near all its margins	*N. vestigator*
	Thorax without hairs	5
5	The yellow bands across the elytra both interrupted at the mid-line by black; tail with a fringe of grey hairs	*N. interruptus*
	The yellow bands on the elytra (or at least the front one) not interrupted at the mid-line; tail with a fringe of golden brown hairs	*N. investigator*

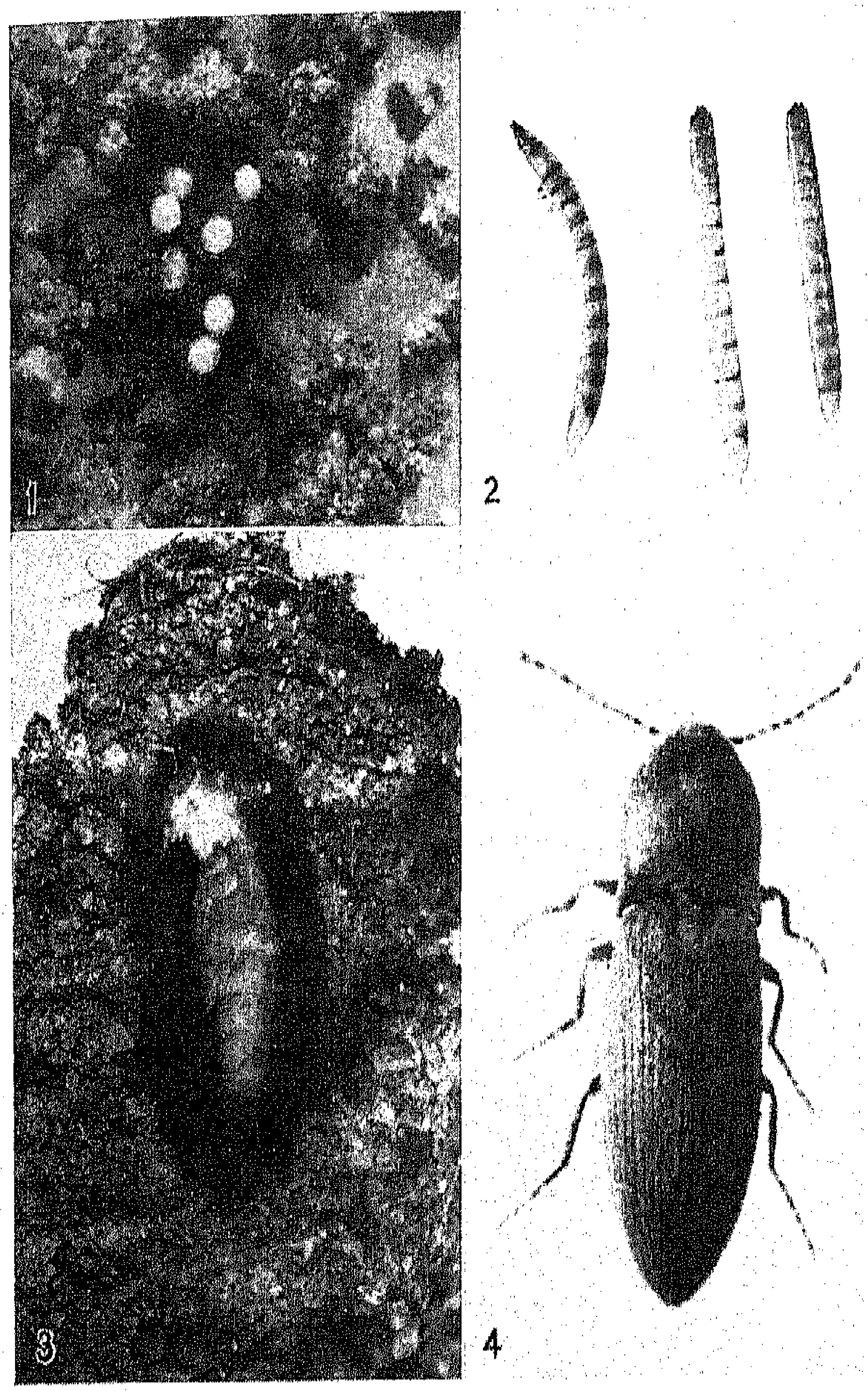
Pronunciation:

N. humator	(hu-may-tor)
N. vespillo	(ves-pil-lo)
N. vespilloides	(ves-pil-loyd-eez)
N. vestigator	(ves-te-gate-or)
N. interruptus	(in-ter-rupt-us)
N. investigator	(in-ves-te-gate-or)

The Click Beetles are interesting because of the way they have of righting themselves when they fall on their backs. The head and front part of the thorax is suddenly jerked backwards against the rest of the body and then the insect leaps into the air where it turns a somersault to land the right way up. This process is accompanied by a sharp click—hence the name.

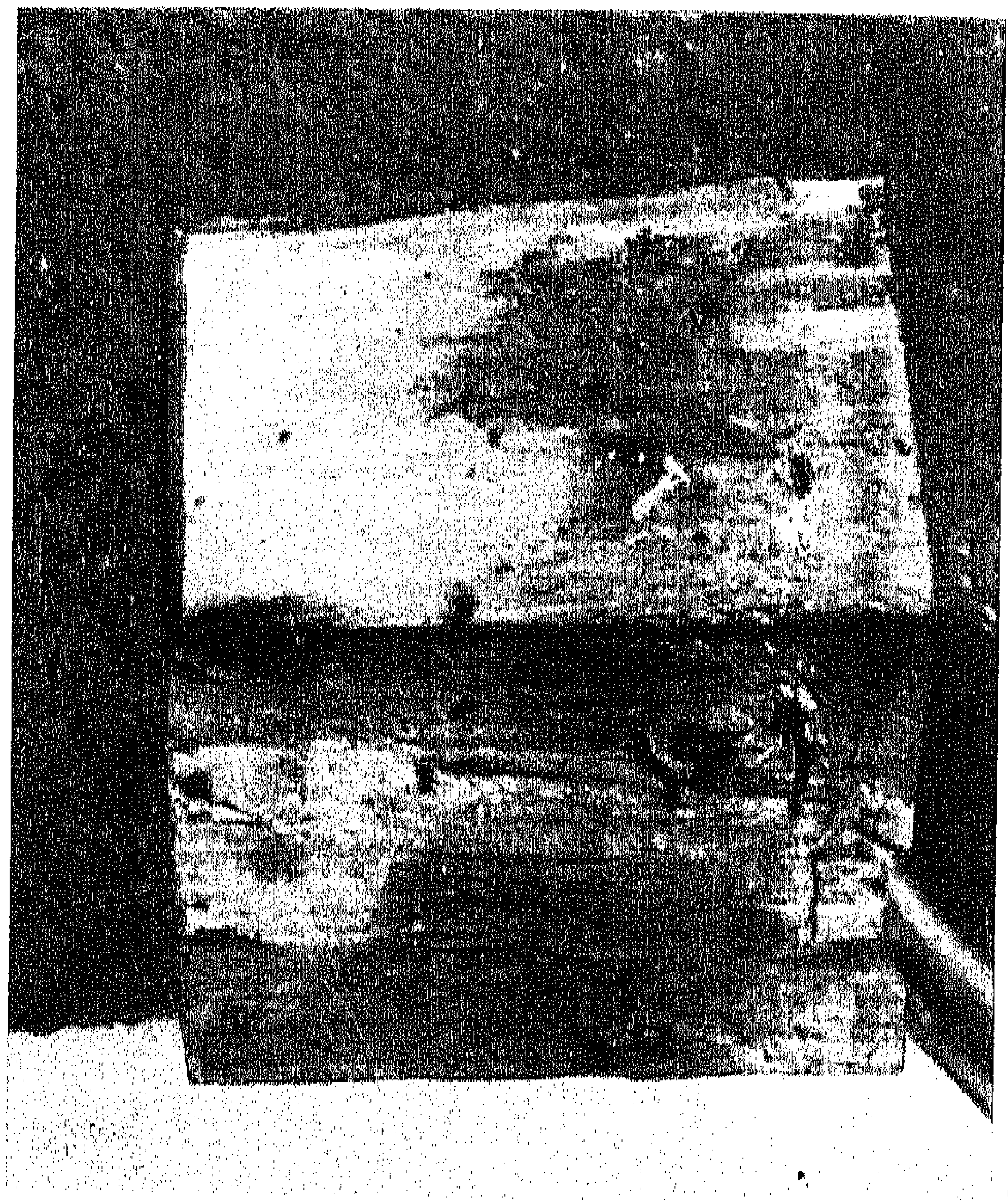
When these beetles are alarmed, they draw their legs closely against the body. As the body is long and rather cigar-shaped, a Click Beetle is difficult to pick up, tending to slip out of one's fingers.

PLATE V

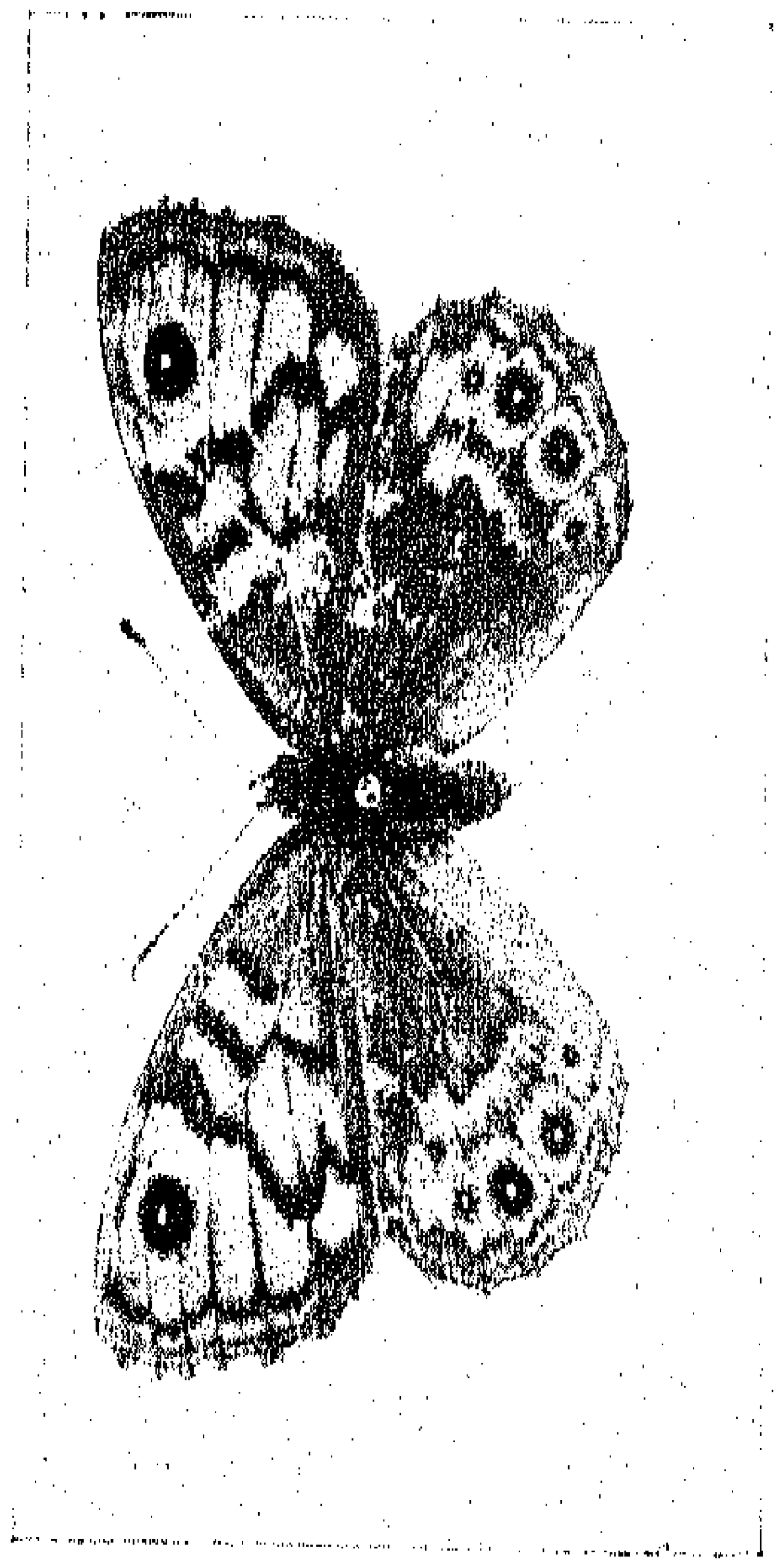


Stages in the life cycle of the Click Beetle (*Agriotes obscurus*). (1) Eggs in the soil. From these hatch the wireworms (2) which live in the soil for four or five years. At the end of that time they make an earthen cell and pupate in it in the autumn (3). The adult Click Beetle (4) emerges from the pupa in September, but remains in the cell until the following spring. The adult beetles usually die before the following autumn. (*Through the courtesy of Professor H. W. Miles.*)

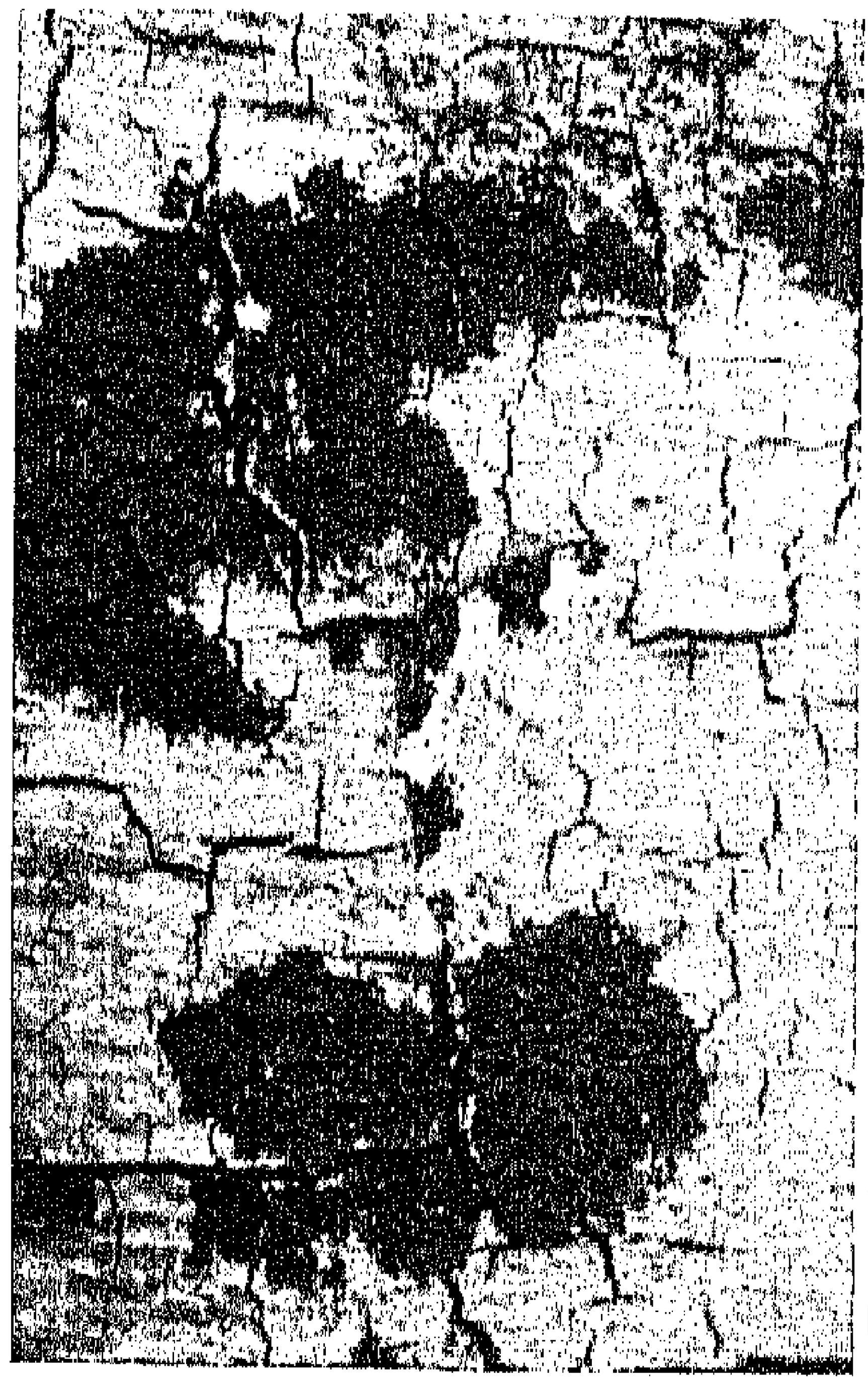
(1) × 5; (2) *somewhat enlarged:* (3) and (4) × 2½



C.—Bark beetles (*Hylurgops palliatus*) on trunk of felled larch. A strip of bark has been turned back. On it can be seen two of the characteristically shaped galleries. On the wood of the trunk are visible the shallow grooves made by the beetles which correspond to the galleries made in the bark. In the lower groove a beetle can be seen at work. The larch had been felled about six months, and the sap was beginning to dry out. (*About natural size.*)



A.—Wall Butterfly showing the mark of a bird's beak across the 'eye-spot' on the wing.



B.—Garden Carpet Moth at rest on an elm trunk, showing how inconspicuous it is on its normal background. (*Both from H. B. Cott's* Adaptive Coloration in Animals. *Methuen.*)

The general shape of all Click Beetles is the same (Plate V). The thorax is always drawn out into sharp angles at the back corners, and the antennæ are saw-like. On the underneath of the front part of the thorax is a backward pointing peg which fits into a groove. It is this peg that makes the clicking sound mentioned above.

The members of one group of the Click Beetles lay their eggs in the soil. The larvæ hatch out and feed on the roots of plants such as grass and wheat, doing much damage. These larvæ are the wire-worms, pests well known to farmers. They are about as thick as the lead in a pencil and, when fully grown, more than half an inch long. The body is golden yellow in colour and very tough (Plate V). The wireworms live for four or five years in the soil before they pupate and finally turn into adult beetles. The beetles are very common on grassland that has been long undisturbed.

Longicorns: The *Longicorn* (lon-je-korn) beetles are most easily recognised by the general shape of the body, which is slender (Fig. 172), and the long threadlike antennæ may be as long as, or longer than, the body. There are other beetles that have a similar shape and long threadlike antennæ, but in those the body and elytra are rather soft, whereas in Longicorns the elytra and body are quite hard, often remarkably so. In addition, Longicorns' feet each have four segments.

One Longicorn that is quite distinct is *Clytus arietis* (kli-tus ayr-e-eetis). This is a slender beetle that at first suggests a wasp (Plate VII). It is black but the elytra have two vivid yellow bands. It flies freely on sunny days and is fairly widespread.

Longicorns are best sought for in woods, and some may be discovered by splitting open old tree stumps with a chisel. The individual beetles are usually fairly large, but there are not a great many different species.

Beetles Living in Water

In fresh water numerous beetles are to be found, but they do not all belong to the same classificatory group. However, provided this is fully appreciated, it seems best to treat the water beetles as a unit, since water does form a quite definite habitat and such beetles are in some ways markedly different in structure and behaviour from those living on land.

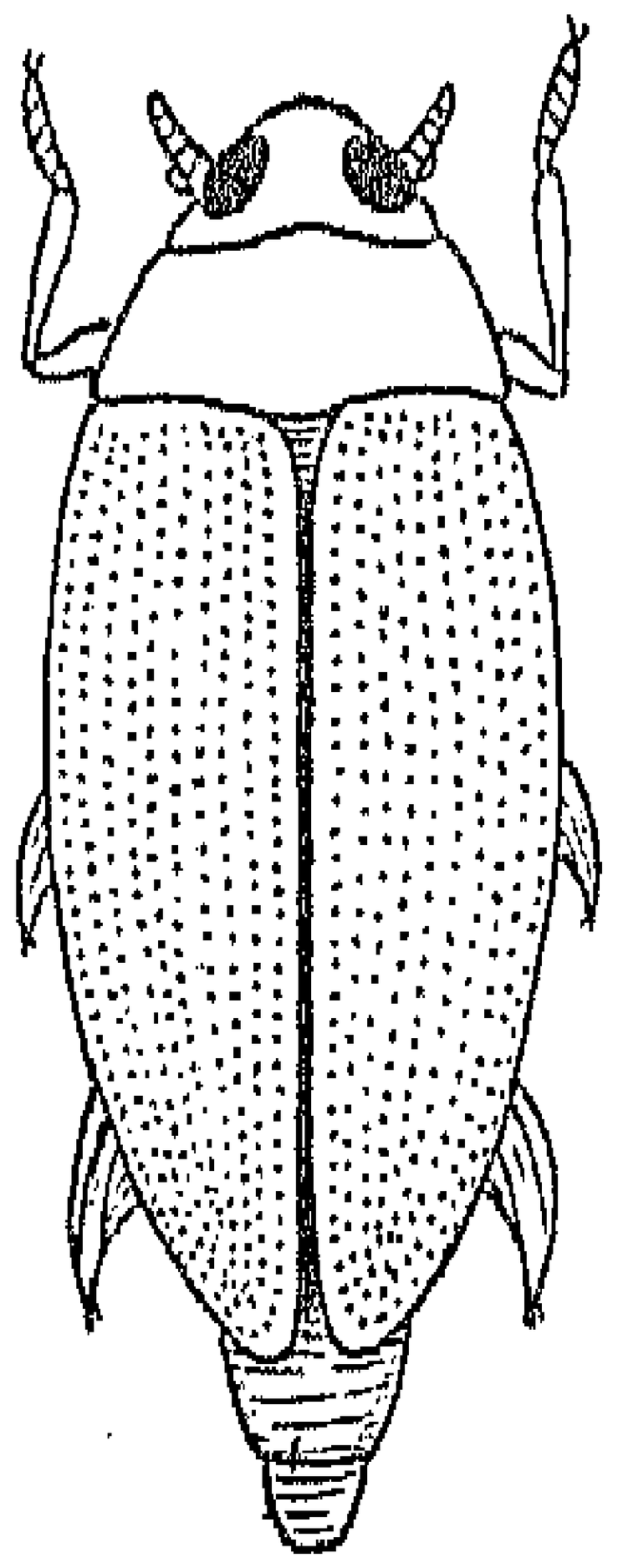


FIG. 79.—Whirligig Beetle (*Gyrinus spp.*), ×6. Note how the limbs are modified to form paddles.

On the surface of fresh water you may come across a colony of Whirligig Beetles whose members are constantly moving along their labyrinthine courses on the surface film (Fig. 79). The small beetles row themselves along with the second and third pairs of legs, which are quite short and serve as paddles. The beetles are black, but so highly polished that they appear white in bright sunshine. They feed on insects which, having fallen into the water, become trapped in the surface film. If alarmed, Whirligig beetles immediately dive below the surface. Their eyes are interesting because they are divided into two parts, so that there appears to be four compound eyes in all. The top part of each eye is said to be used for seeing in air while the bottom part is employed for underwater vision.

Other water beetles live mainly below the surface, though usually they are capable of coming on to land and flying some distance to fresh patches of water. They are, in general, rather oval in outline and more or less stream-lined, or at least the head, thorax, and abdomen all fit snugly into one another leaving no projecting parts (Fig. 80). This, no doubt, helps to cut down the drag offered by the water to the movements of the beetles.

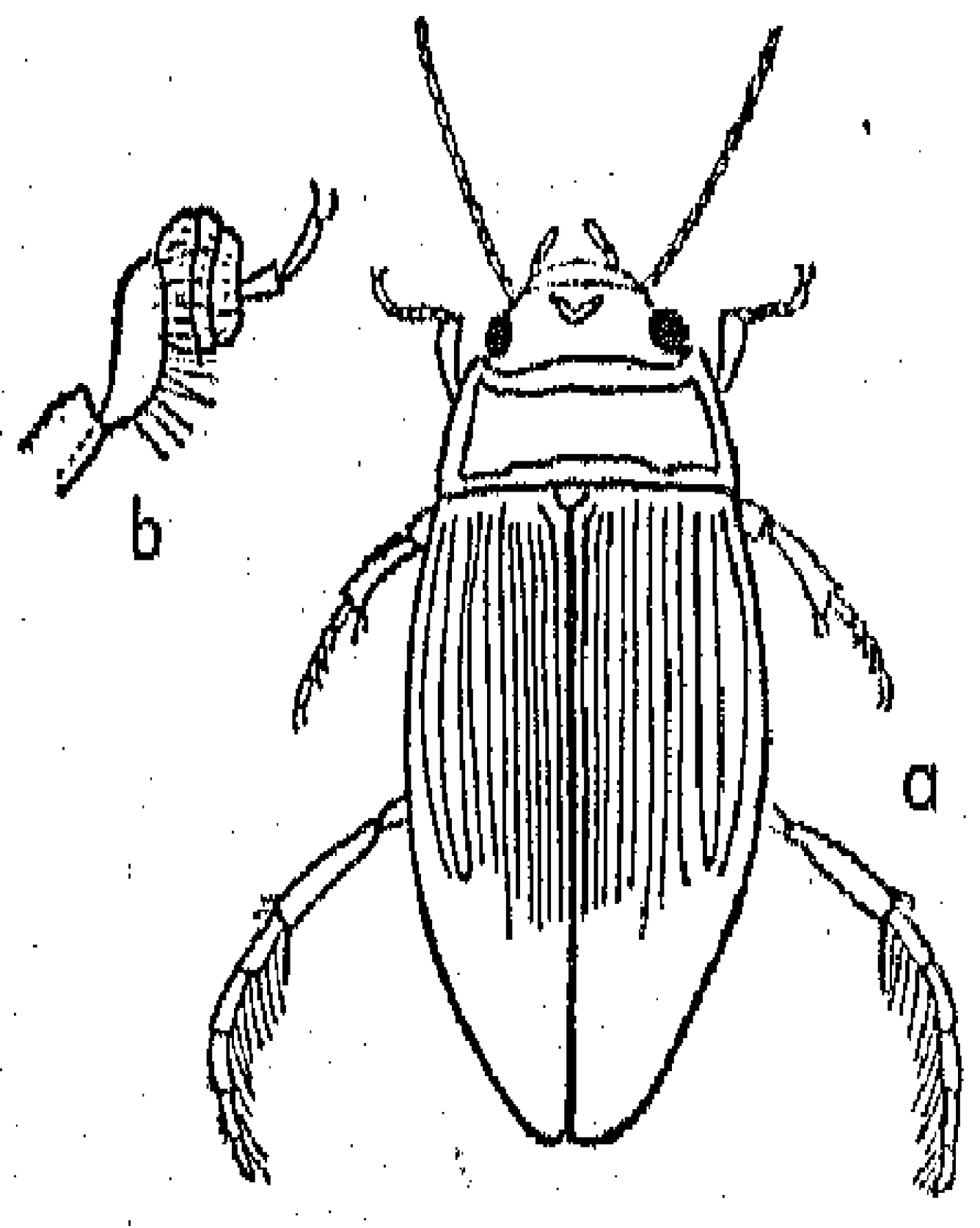


FIG. 80. — (*a*) the Great Diving Beetle (*Dytiscus marginalis*), female, ×1: (*b*) the sucker developed from the first three segments of the tarsus in the male, ×2.

Most water beetles come to the surface at frequent intervals for air. The air is trapped under the elytra and finds its way from there into the breathing tubes. The respiratory behaviour can easily be watched by keeping water beetles in small aquaria or jam-pots. Since most water beetles are carnivorous it is unsafe to place the bigger ones in aquaria containing other small water animals.

The hind legs of most water beetles are used as paddles, and so look rather different from normal beetles' legs. In some species of water beetles the front legs of the males have suckers which are used to hold the females during mating. This is so in the large water beetle usually called the Great Diving Beetle, *Dytiscus marginalis* (di-tisk-us mahrj-in-aye-lis) (Fig. 80). This common beetle is about $1\frac{1}{4}$ inches long. The general colour is a pitchy brown varying to a greenish black, but the sides of the elytra and thorax are yellowish brown. The females usually have ten or eleven grooves on each elytron, whereas those of the males are quite smooth. In addition, the males have the large suckers on the front feet that were mentioned above. Sometimes you will come across *Dytiscus* beetles which have smooth elytra (suggesting that they are males) but no signs of the suckers. Actually these specimens are females that for some reason have failed to develop the grooves on the elytra.

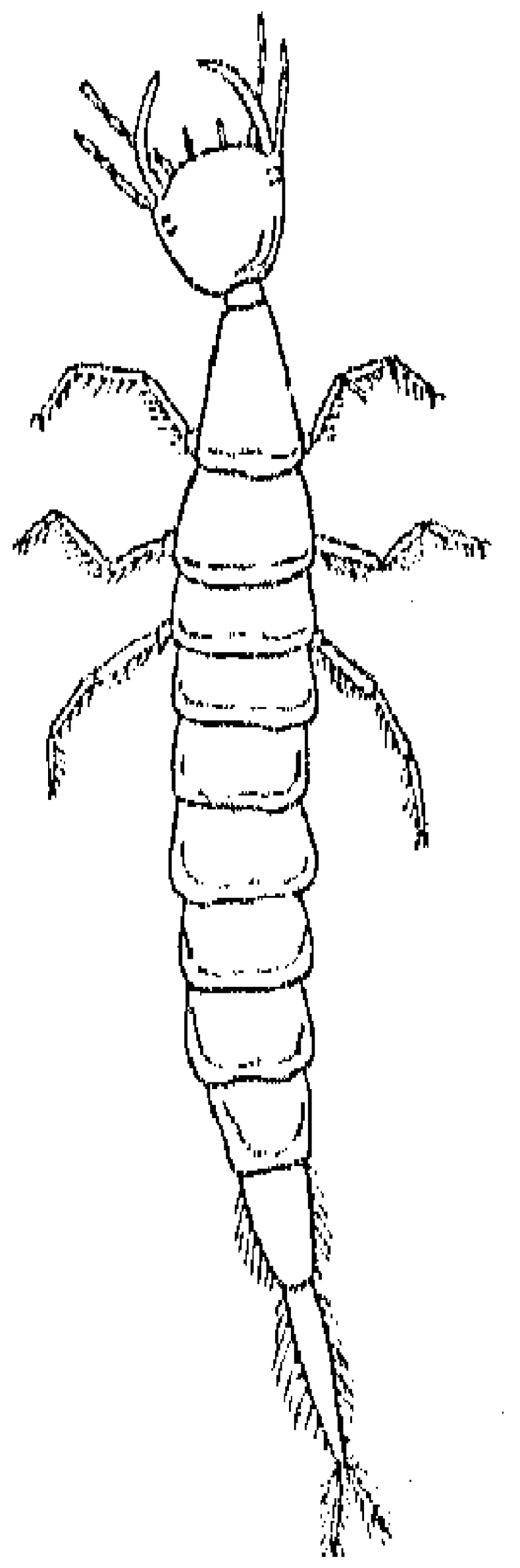


FIG. 81.—Larva of *Dytiscus marginalis*, ×1.

The larvæ of the Diving beetles are fierce (Fig. 81). They live crawling about on the floor of the pond where they dwell, but, when they are mature, come out of the pond and dig a hole in the bank nearby. In this hole they pupate and ultimately turn into adult beetles, the whole process taking about three weeks.

If you catch a *Dytiscus* larva when hunting in a pond with a water net, you can keep it alive in water by feeding it on

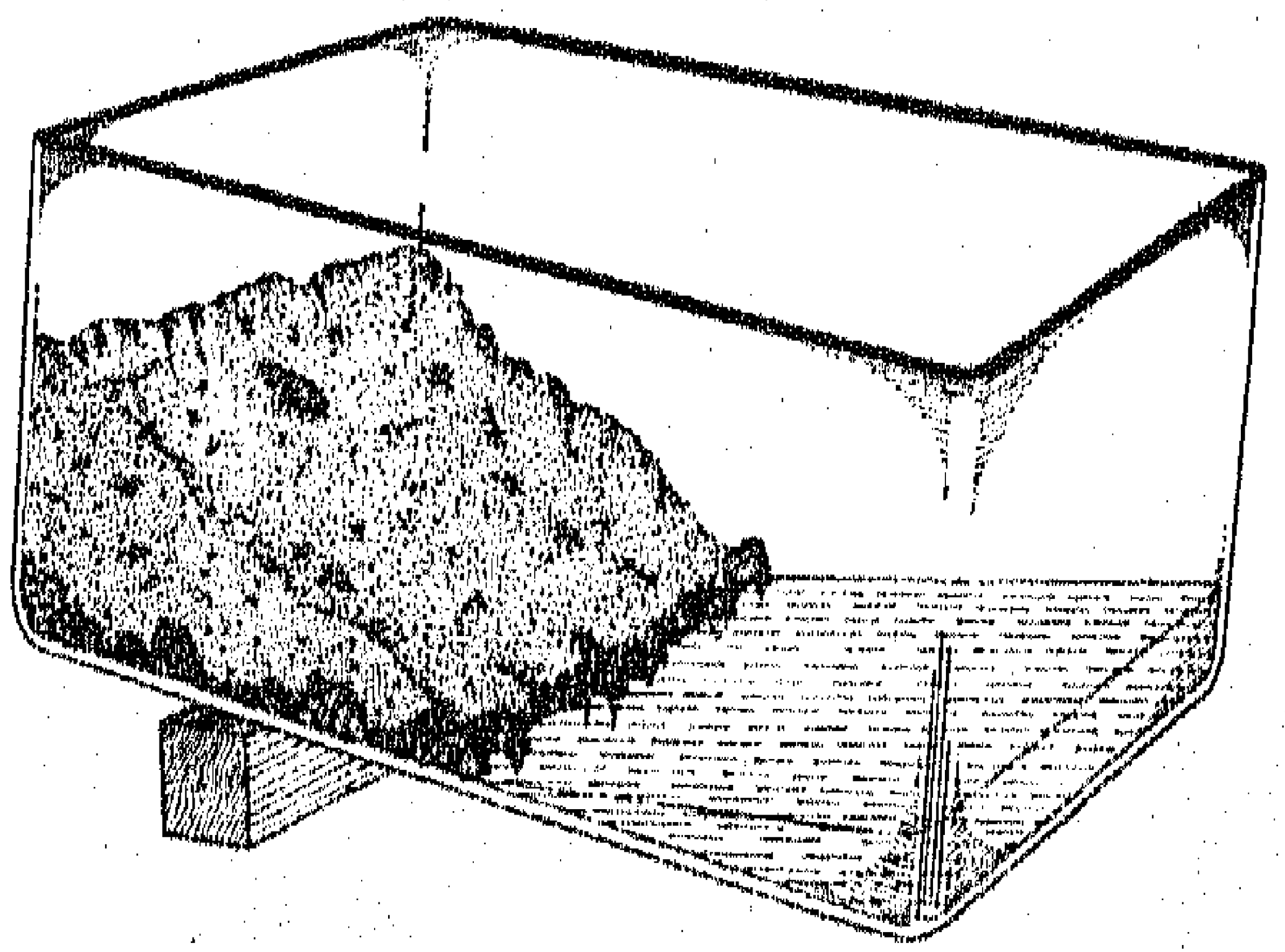


FIG. 82.—Arrangement of an aquarium for rearing Great Diving Beetles.

maggots or small pieces of meat. The best way is to tie a small piece of meat on to a piece of cotton and drag the meat in front of the larva which, if hungry, will readily attack it. Any meat which is not eaten must be removed after a day or it will cause the water to become foul. Fig. 82 shows how to arrange an aquarium if you wish to rear adult beetles from larvæ. The soil is for the larvæ to pupate in.

How to Collect Beetles

Beetles are an easy and satisfying group to collect. You will come across many specimens at rest on flowers, running actively on the ground, or flying, when they may be taken with a butterfly net. Others may be obtained by sweeping long grass and similar tall vegetation with a sweep net (see p. 8) especially during May and June. Under the loose bark of old tree trunks, in manure, on flower blossoms, in moss, on the fruiting bodies of fungi, and in sand pits, are other favourite habitats of certain species, while many others may be obtained by shaking or beating the leafy branches of trees and shrubs over a white sheet.

Beetles can be killed in a laurel leaf bottle or by being dropped into a little boiling water in a tin lid or egg cup. After they are dead, it is usual to set them so as to display the legs and antennæ before they dry out and become stiff. Fig. 75 shows a set beetle. The legs and antennæ are spread out with a brush or needle and kept in position on a cork mat with pins. Large beetles may take five or six days to become stiff. Before being set, these larger beetles are usually impaled on insect pins, which are passed through the right elytron just behind the shoulder.

Smaller beetles are usually set on white cardboard by the use of gum tragacanth. This is obtained from the chemist as a white powder. When a little is added to a drop of water, it swells to form a clear stiff gum, though this may take some time. When the gum dries on the white card it becomes invisible. As before, the beetle's legs and antennæ are spread out, being held in position by the gum.

CHAPTER FIFTEEN

The Order of Two-Winged Insects

(DIPTERA)

If you catch one of those clumsy insects we call Daddy Long Legs (Fig. 83) and examine it, you will see that it has only one pair of wings. Attached to the thorax, where we should expect to find the second pair of wings, is a pair of club-shaped structures called "balancers" (Fig. 83). Each balancer is rather like a short pin with an oval head and is quite unlike a wing. But there is good reason to believe that each balancer does in fact represent a wing. You will find that house flies and blue bottles also have each only one pair of wings, and possess these peculiar balancers in place of the hind wings.

All these insects which have but one pair of wings and have balancers in place of the hind pair of wings are called *Diptera*

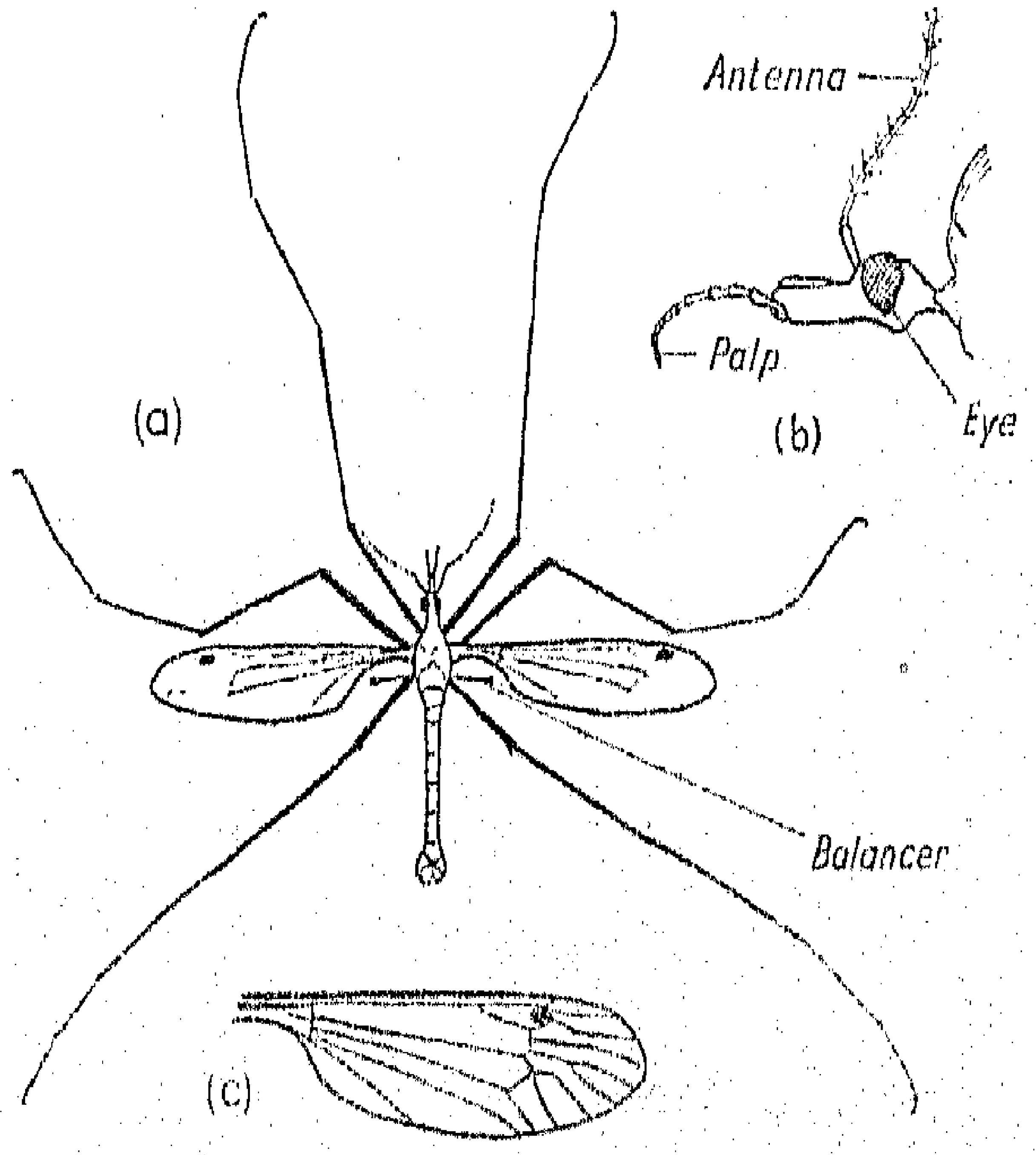


Fig. 83.—(*a*) adult female Daddy Long Legs, ×1; (*b*) enlarged view of the head, ×4; (*c*) wing, to show vein pattern, ×1½.

(dip-ter-a). The name is made up from two Greek words—*Di* meaning two, and *Pteron* meaning a wing.

If you catch a blue bottle and, holding it by one wing, look at the balancer of the opposite side through a hand lens, you may see the balancer from time to time start vibrating up and down with a very rapid motion as the insect tries to fly. It is thought that this vibrating motion takes place while the insect actually is flying, and that it helps to keep the insect stable in the air. Probably it is harder for an insect with two wings to fly, than it is for an insect with four wings.

There is nothing else very different from the normal insect pattern in the structure of a Daddy Long Legs. The drawings in Fig. 83 will show you the main features. The female Daddy Long Legs can be distinguished from the male by the shape of the abdomen. In the females it is blunt and more or less swollen at the tip, whereas in males it tapers to a fine point and is longer in comparison. The females lay their eggs in grass and these hatch into larvæ called leatherjackets which often do considerable damage to turf.

The life cycle of the Daddy Long Legs is difficult to follow with the facilities one normally possesses at home. In the Mosquitoes (another group of insects belonging to the *Diptera* order) the life cycle is much easier to observe, and in some ways it is more interesting because the early stages are passed in water.

The Mosquito

The general structure of a mosquito is shown in Fig. 84*a* and the details of the wing pattern in Fig. 84*c*. Under a hand lens, the veins of the wings will be seen to be covered with scales, and there is a distinct fringe of scales along the hind edges of the wings. Another characteristic of mosquitoes is the long proboscis (or snout) that sticks out from the front of the head. Inside this snout, in females, are sharp piercing mouthparts that enable these insects to pierce skin and suck blood. Only the females suck blood.

The males can easily be distinguished from the females because they have feathery antennæ, whereas the antennæ of females appear threadlike to the naked eye, though under the hand lens they will be seen to bear a number of very fine and quite long hairs.

The species I have drawn is the Common Gnat, *Culex pipiens* (kew-leks pi-pee-ens), and it is one of the most abundant. It is quite easy to rear it and to see all the stages in its life history. The specimens from which the drawings were made were all reared indoors in jam-pots, during the month of June.

The eggs of *Culex pipiens* are laid in almost any pool of stagnant water, which contains rotting material such as leaves to supply food for the tiny creatures on which the mosquito larvæ feed. The female *Culex* lays a number of eggs at one time. The eggs are cemented together to form a raft which floats on the surface. Rainwater barrels and cisterns, if exposed freely to the air, are favourite places, but you might try leaving in a shady place three or four jam-pots full of water shaken up with a little manure or garden soil. Mosquitoes will probably lay eggs in them during the summer months. Sooner or later, at a period dependent on the temperature, the eggs hatch and the young larvæ emerge from the end of the egg

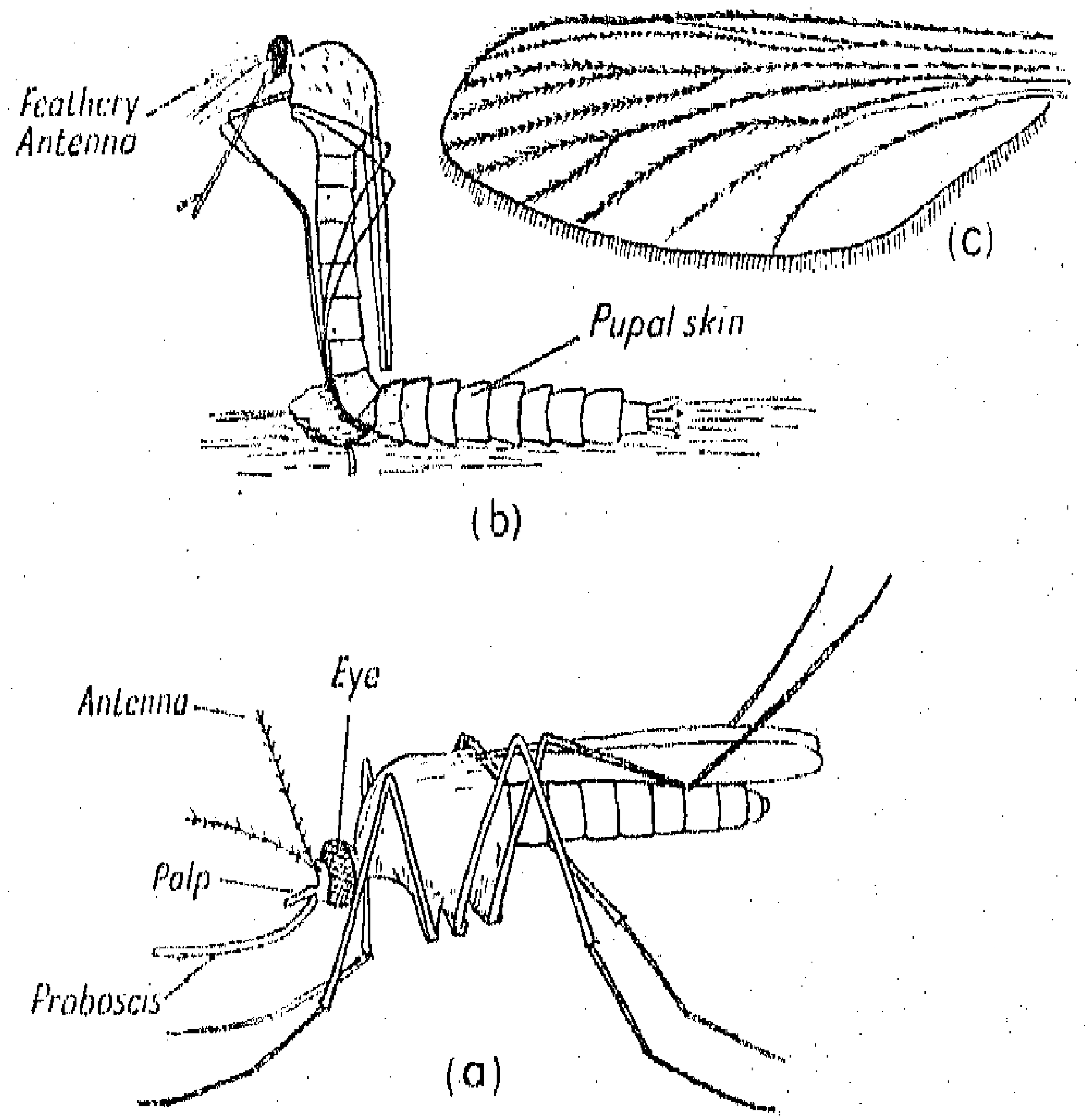


Fig. 84.—(*a*) adult female of the Common Gnat (*Culex pipiens*), in its normal posture with the body parallel to the surface upon which it is standing; (*b*) male Common Gnat hatching from the pupa which floats at the surface of the water; (*c*) wing, to show the vein pattern; note that the veins are fringed with scales. [(a) and (b) × 4; (c) × 6.]

which floats beneath the water. The larvæ live entirely under water but at intervals come to the surface to breathe. The structure of a *Culex pipiens* larva is shown in Fig. 85*a*. The abdomen consists of nine segments, the breathing tube being situated on segment eight. When the larva wishes to renew its supply of air, it wriggles its way to the surface, pushes the breathing tube through the surface film, and hangs motionless. After a time it breaks away again and lashes its way to the bottom. Here it may be seen cruising around, its jaws working vigorously. In the drawing (Fig. 85*a*) two little black balls are shown. These are pellets of waste matter that have come from the end of the food canal which opens on the last segment. The food canal, with dark food material in it, can be clearly seen through the skin of the larva, and, if you watch a larva for a few minutes through a hand lens, you are almost sure to see the waste pellets passed out from the body through the anus. To observe the larvæ of *Culex* through a hand lens I have found it best to place one or two in a small glass tube (e.g., an aspirin tube) with an inch or so of the water in which they were previously living.

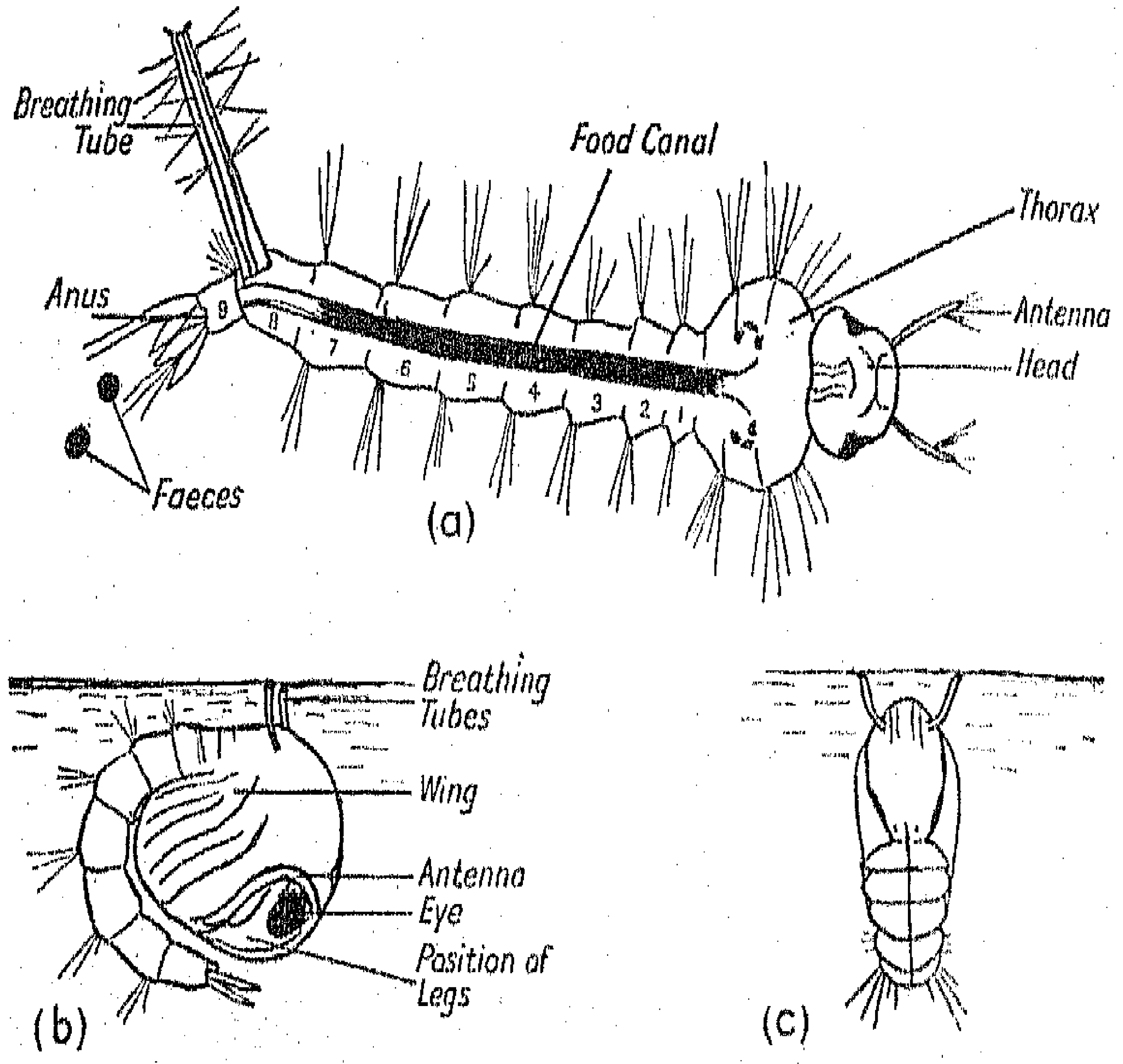


FIG. 85.—(*a*) larva of the Common Gnat, *Culex pipiens*, ×6; (*b*) and (*c*) two views of the pupa suspended from the surface film of the water in which it is dwelling, ×5.

The larvæ grow rapidly, and, to make increase in size possible, they have to cast their skins, as do all animals whose skeletons form a complete case around the body. They moult three times, then they turn into pupæ. The pupæ of *Culex* are curious little creatures that float just below the water surface, but, if disturbed, they can wriggle into the depths in a fussy manner. They consist of an ungainly portion at the front which is made up of the head and thorax, and behind this the abdomen which is curled round as shown in Fig. 85*b*. The single breathing tube of the larva has disappeared, but in its place two new breathing tubes have been developed (Fig. 85*c*). These pierce the water surface and allow air to pass into the pupa. The pupa no longer feeds, so the active jaws are missing.

It is not easy to distinguish the detailed structure of the pupa with a hand lens as the pupa is rather dark; but the eyes can be seen, together with indications of the wings. After a few days, the actual time depending on the temperature, the pupa splits along the dorsal side and the adult insect pushes its way out (Fig. 84*b*). The empty pupal skin floats at the surface and acts as a raft on which the mosquito can stand until its tissues are sufficiently hardened to enable it to fly off.

If you obtain some eggs or larvæ, they can be reared into adults quite easily in a jam-pot of water with a piece of cloth over the top, and you will be able to see all the stages. The live adults are best examined in a corked glass tube since they are rather too delicate to withstand handling.

You will know that certain mosquitoes infect human beings with the germs of malarial fever. Another kind carry the germs of yellow fever which they can transmit to humans. In regions where these two diseases are common, a good method of preventing their spread is to stop mosquitoes from breeding. This can be done by draining away as much standing water as possible, or, in such stretches as cannot be drained, by killing the larvæ. If a pool containing mosquito larvæ is sprayed with crude paraffin, the oil forms a thin film over the surface and enters the breathing tubes of the larvæ. I suggest you take a small tube full of water and place a few larvæ and pupæ in it. Then try the effect of adding a few drops of paraffin oil to the surface. At the same time prepare another similar tube, without adding any oil. Any difference in the length of life of the pupæ and larvæ in the two tubes must then be due to the oil.

The species of mosquito that carry malarial germs belong to the genus ANOPHELES (an-off-el-eez). There are four species present in the British Isles. The adult insects of the *Anopheles* genus can be distinguished from the non-malarial carrying mosquitoes by the way they stand, for the body is held pointing away from the surface on which the insects are resting (Fig. 86). The larvæ can be distinguished by the absence of the breathing tube on segment 8, and by the fact that the whole larva floats close to the water surface. Fig. 86 should make these points clear. Keep a sharp look out for mosquitoes at rest and determine whether they belong to the malarial-carrying group or not. Do the same for any larvæ you find. Incidentally, good places to search for mosquito larvæ during the later summer months are the "rot holes" which occur in trees where branches have decayed away. These often contain a mass of sodden wood and decaying leaves, and frequently a considerable amount of water. A tablespoon lashed to a stick will enable you to extract the contents from the smaller holes.

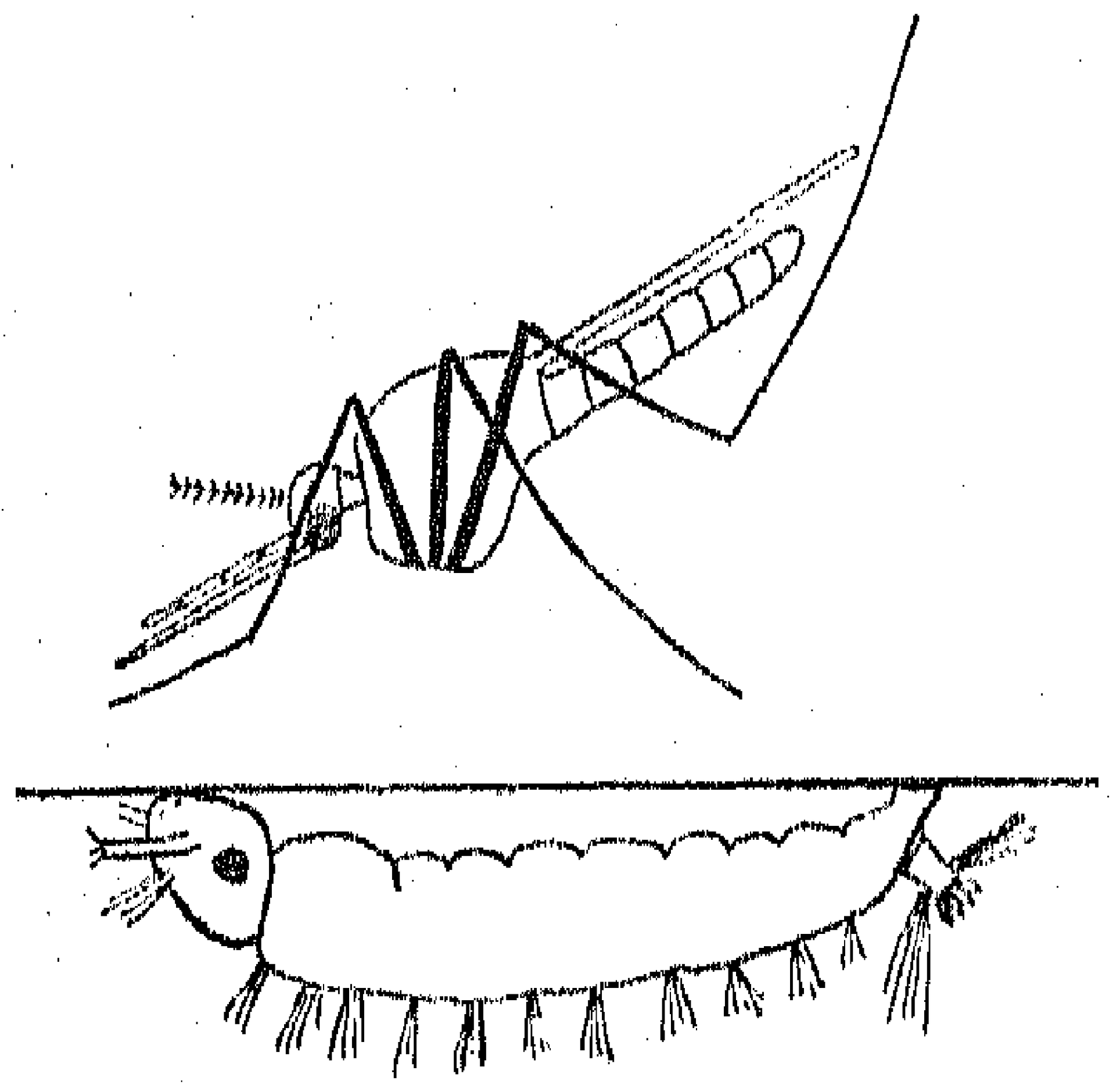


FIG. 86.—*Above:* diagram of the mosquito, *Anopheles*, standing in its normal posture. *Below:* diagram of the *Anopheles* larva, which hangs suspended parallel to the surface film.

The key below will help you to distinguish between the four species of *Anopheles* that occur in Britain. First make sure that your specimen belong to this genus by observing the way it stands (Fig. 86). It should have no scales on the abdomen—the other group, the *Culicines* (kew-lis-eens) have the abdomen densely covered with scales. The females can be distinguished from the males by the antennæ. The males have bushy antennæ, whereas the antennæ of the females have only a few thin hairs.

KEY TO THE BRITISH ANOPHELES

1	Insect with a tuft of white scales at the front of the forehead	2
	Insect without a white tuft (very rare)	*Anopheles algariensis*
2	Insect with small dark spots on the wings	*A. maculipennis*
	Insect without small dark spots on the wings	3
3	Insect brown; tuft at front of head dirty white	*A. claviger*
	Insect blackish, with often a lighter stripe down the back; tuft of scale on front of head pure white	*A. plumbeus*

Pronunciation:

A. algariensis	(al-jay-re-en-sis)
A. maculipennis	(mak-yewl-e-pen-nis)
A. claviger	(klav-ij-er)
A. plumbeus	(plum-bee-us)

In addition to mosquitoes, house flies, and blow flies, there are numerous other kinds of insects that have only one pair of wings and so belong to the *Diptera*.

The brightly striped hover flies, that on sunny days hang poised motionless in the air over our garden flowers, suddenly to dart about with great rapidity, are interesting because so many townsfolk mistake them for wasps or bees. They are quite harmless to humans.

CHAPTER SIXTEEN

Plant Lice and Bugs

THE *Hemiptera* (he-mip-ter-a) forms an order of the insect class which is made up of a variety of forms. It includes the plant lice (the green and black flies which are such pests to gardeners), bed bugs, frog-hoppers (whose larvæ make the familiar cuckoo-spit on flowers), pond-skaters, water-scorpions, water-boatmen, and a considerable number of other forms. These are all alike in having the mouth drawn out into a kind of beak which is of use only for piercing the skins of plants or animals and sucking their juices. When not in use, this beak is folded back underneath the body (Fig. 87*b*).

Members of the *Hemiptera* have two pairs of wings whose nature can be used to divide the group into two smaller groups, the *Homoptera* (hom-op-ter-a) in which the fore and hind wings are very similar, and the *Heteroptera* (het-er-op-ter-a) whose members possess markedly dissimilar fore and hind wings.

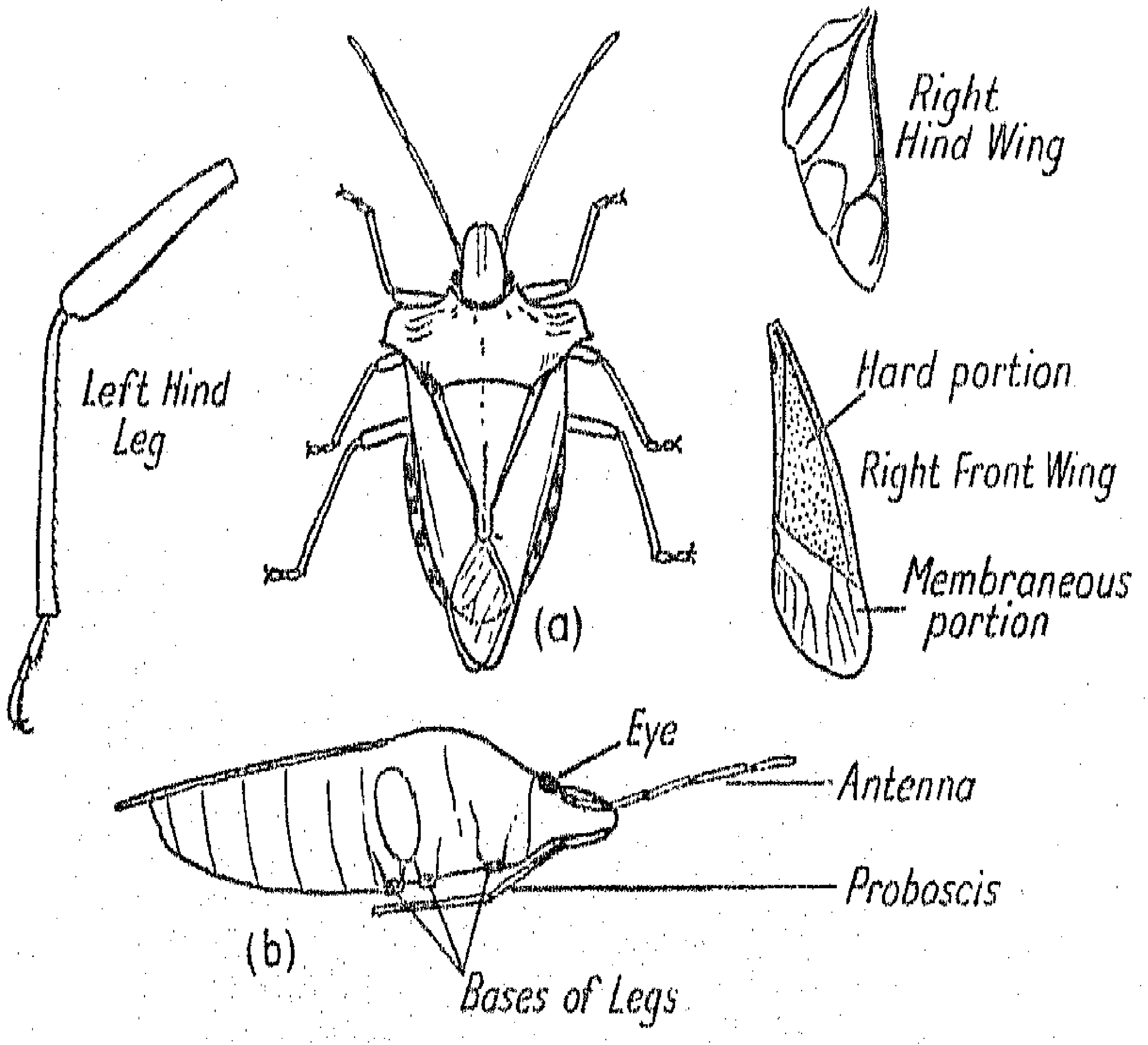


FIG. 87.—(*a*) an adult Shield Bug, ×2; (*b*), side view of same to show the proboscis folded back under the body, ×2½; wings, ×2; leg, ×4.

Hemiptera Homoptera: Green and Black Flies

The *Homoptera* include the familiar *aphides* (af-e-deez) or GREEN and BLACK FLIES. There are quite a number of these, all very similar in outer structure, so it matters little which kind you obtain to study. They are all small.

If you look during spring on the tender shoots of roses, sycamores, hawthorns, and many other plants, you are almost certain to find aphides in considerable numbers. Some will have wings and some will be without.

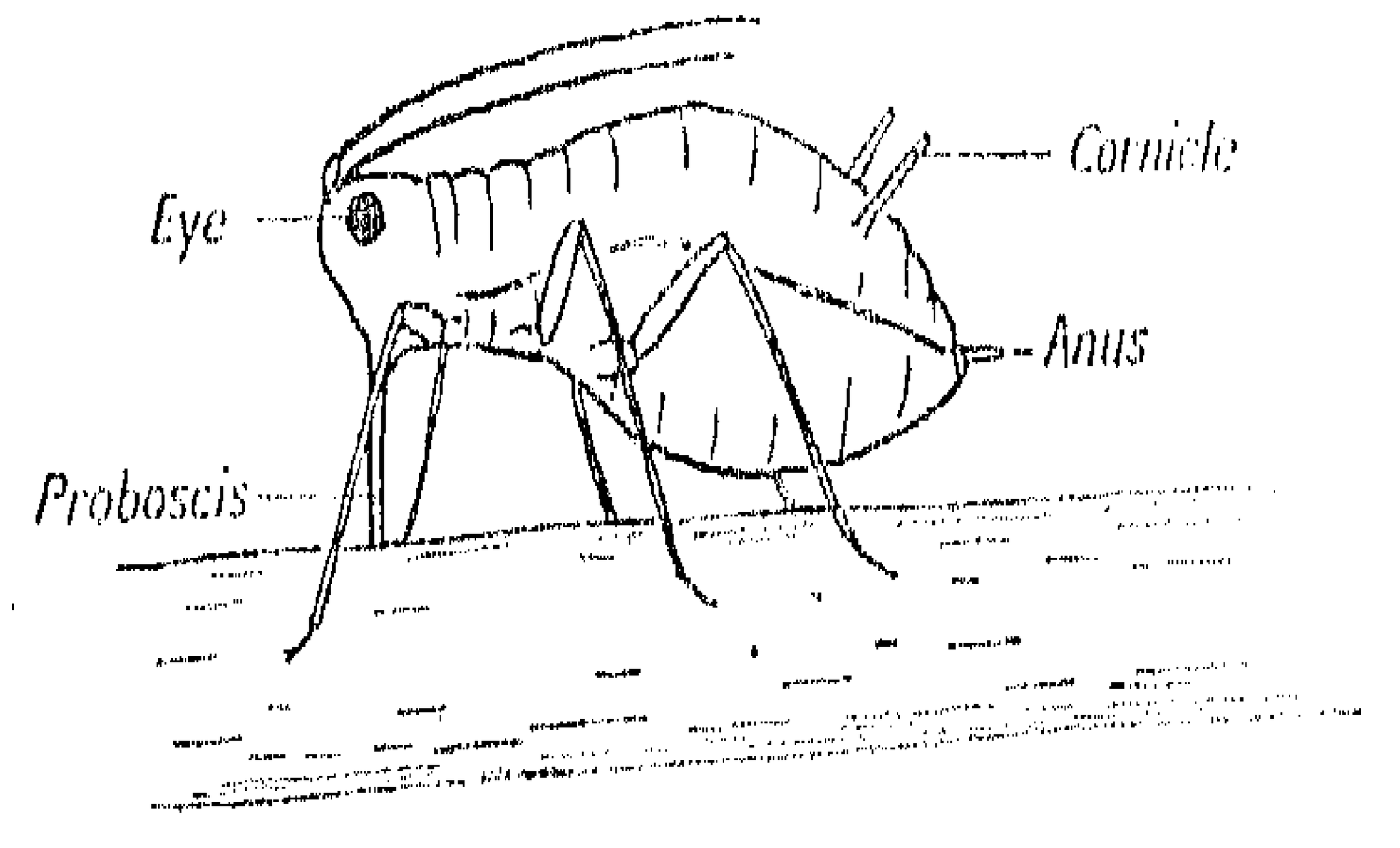


FIG. 88.—Wingless form of aphis, feeding on rose, ×15.

The insects are small, and many will be stationary, sucking the plant's juices. A few will be walking about. Select one of these which has wings and transfer it to your thumb nail, using a brush or a grass stalk. Now examine it with a hand lens and you will be able to discern much of its structure (Fig. 89).

The body is fat, and not very distinctly divided into head, thorax, and abdomen, although these can be distinguished. The most conspicuous structures on the head are the eyes which, in green-flies, appear as two black dots. The antennæ are long and thin, and may either be carried pointing forwards or else sloping backwards over the body. The front end of the head is produced into a beak which may be difficult to see if it is curved back under the body, but is quite obvious in an insect which is feeding.

The thorax carries three pairs of rather slender legs. The last few segments of each leg, forming the tarsus, are extremely thin. On the thorax also are the two pairs of wings. These are thin membranes and their veins are arranged as shown in Fig. 89. When at rest the wings are folded tent-like over the body in an upright position.

The abdomen is rather round and plump. It shows signs of segments and is drawn out at each side into a narrow ridge or fold. Towards the hind end the abdomen bears on each side a little spike-like structure. These "abdominal processes" give off a waxy fluid, but their use is not well understood. The extreme tip of the abdomen is, in some species, drawn out into a pointed process (Fig. 88).

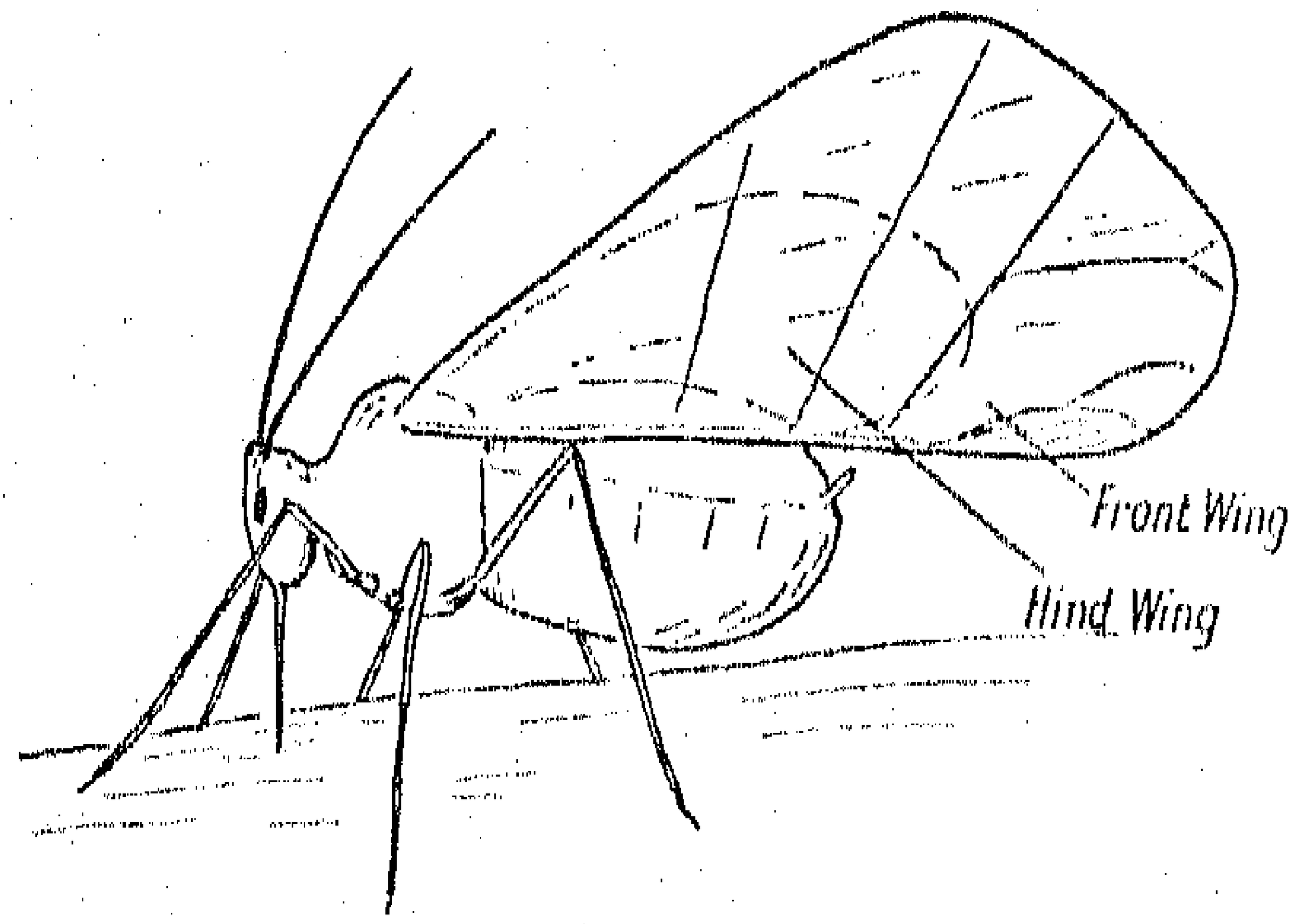


FIG. 89.—Winged form of aphis, feeding on sycamore, × 15.

Green-flies increase in numbers at an extremely high rate. During spring and summer there are no males, and instead of laying eggs in the manner of most insects, the females give birth to well developed young. If you watch through a hand lens a twig covered with green-flies, you may actually see this occur, though a little patience is needed. This year I took the tip of a young rose twig (about 1½ inches long) and, after making sure that it contained no green-flies, I carefully transferred to it with a paint brush one of the fat insects walking about on another rose twig. Then I put the rose twig with its one green-fly into a glass tube about 2 inches long and left it corked. After one week, I counted more than two dozen green-flies in my tube. You could easily repeat this experiment for yourself.

Although no eggs are laid during the spring and summer, some are laid towards the end of autumn, during which time males are also present. These males mate with the females and fertilise their eggs before they are laid. The eggs do not hatch at once, but remain as eggs throughout the winter. When they hatch in spring, they give rise to green-flies with wings. These insects can thus fly about until they find suitable plants to feed upon. They begin feeding and soon give birth to more green-flies which, however, are wingless. These wingless green-flies also commence to feed, pushing their beaks into the plants' tissues and sucking the juices. In their turn they give birth to more green-flies, and so the process is repeated, and in a short time a plant may be thickly covered with these insects.

The green-flies are not without enemies, of course. I have seen birds picking at rose trees thickly covered with the insects. In addition to birds there are many insects that prey upon aphides—the larvæ of the lady bird beetles eat them, and so do the larvæ of lace-wing flies and certain hover flies (see p. 159). If in August you examine a number of shoots of plants infested with green-flies, you will almost certainly see some of these enemies. There may also be ants crawling about the twigs, stopping now and then at a green-fly; but they are not enemies. What they are doing will be clear from p. 292.

Hemiptera Heteroptera: Bugs

Members of the group *Heteroptera* look rather different from the *Homoptera*. Their wings are folded closely over the back, and the front pair of wings are horny at the base. When the wings are folded, this horny part forms a shield over the remainder, and because of this some of these insects look rather like beetles (Fig. 87*a*). They can be distinguished quite easily, since in beetles the edges of the horny front wings (the elytra) make a line running down the centre of the abdomen, whereas in bugs the wings have the appearance of being crossed, the edges of the horny parts and the principal veins together forming an X on the abdomen. Fig. 87*a* should make this clear.

Several members of the group *Hemiptera Heteroptera* are common in fresh water and some are mentioned below.

The Water Scorpion, *Nepa* (nep-a), is a flat water bug about 1¼ inches long. It is found quite commonly in still water and is of a dirty brown colour much resembling the colour of a partly rotted leaf. Fig. 90 shows its structure. The curiously shaped front legs are used to catch animal prey. The breathing tube at the hind end is made of two halves which fit together to make the complete tube. During its life the animal swims

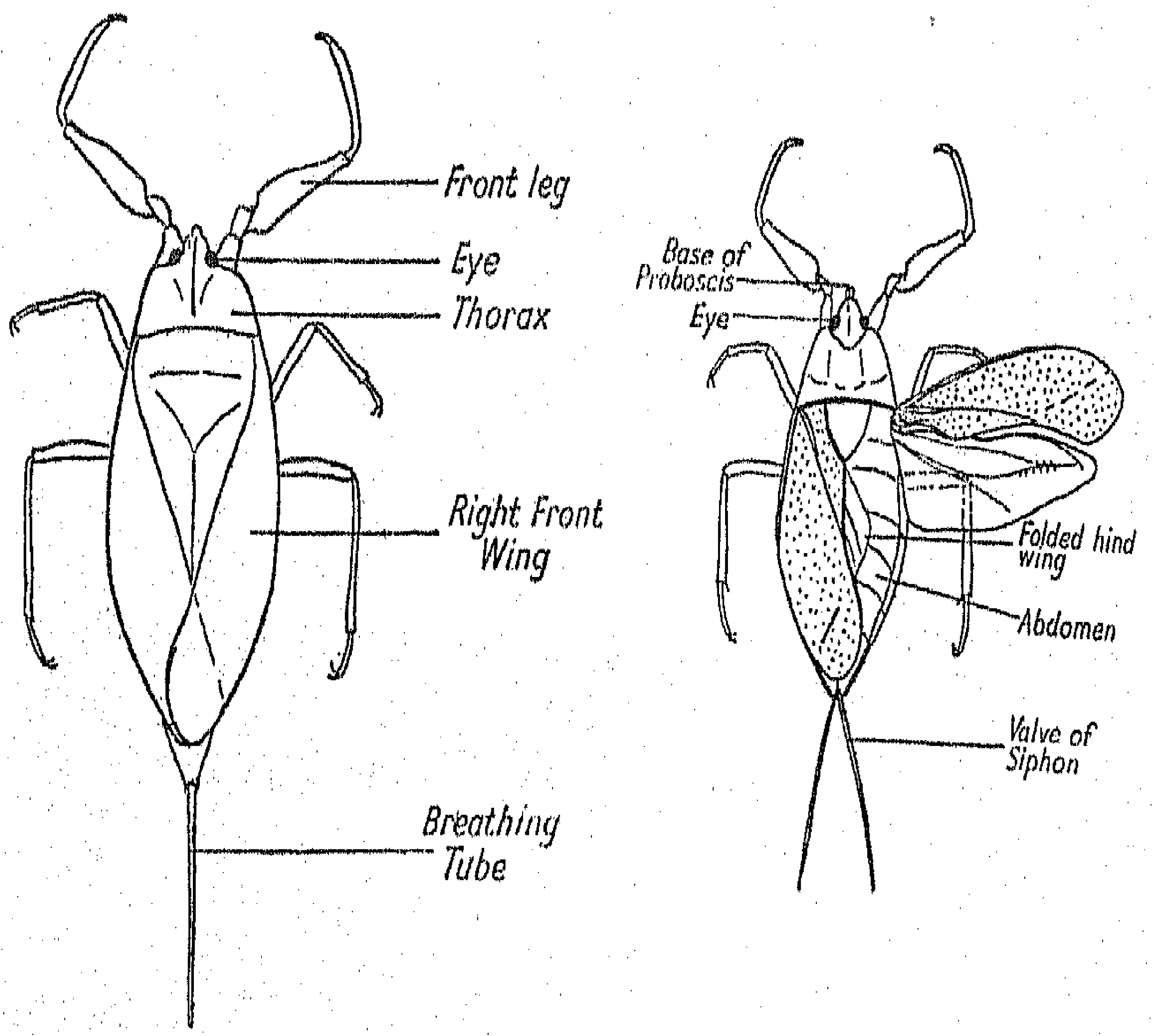


FIG. 90.—*Left:* Water Scorpion, *Nepa*, ×2; *right:* a specimen drawn with the wings of the right side spread to display the abdomen (which is coloured bright red), and the two valves of the breathing siphon separated, ×1½.

at intervals to the surface of the water and pushes the end of this breathing tube into the air to obtain a new supply of oxygen.

A related form is the WATER STICK INSECT, *Ranatra* (ra-nayt-ra). This animal is about 2 inches long and slender in the body. It is much rarer than the water scorpion. Other bugs you will find common in fresh water are the WATER BOATMEN (Fig. 91). There are a number of species of these, but all row themselves along under water by means of their powerfully developed hind legs. These are clothed with a number of hairs which help them to obtain a better push against the water. One form, *Notonecta* (no-to-nek-ta), about ¾ inch long, is remarkable in that it swims on its back. The exposed undersurface has a silvery glistening appearance because of a bubble of air which is trapped in a layer of hairs. This air is used by the *Notonecta* for breathing purposes and the insect has to come to the surface at intervals to renew the bubble as the oxygen in it becomes exhausted.

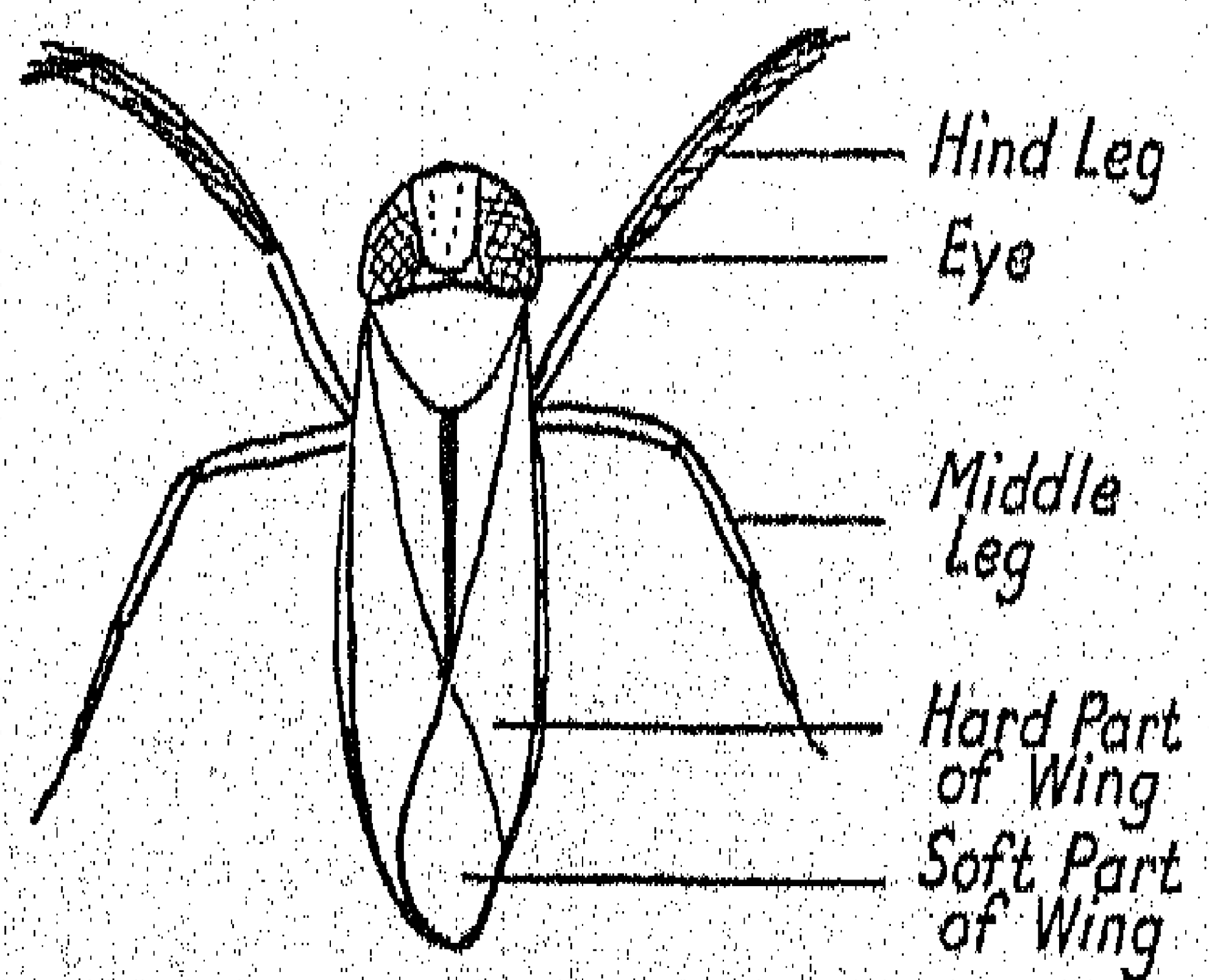


FIG. 91.—Lesser Water Boatman, *Corixa spp.*, ×2.

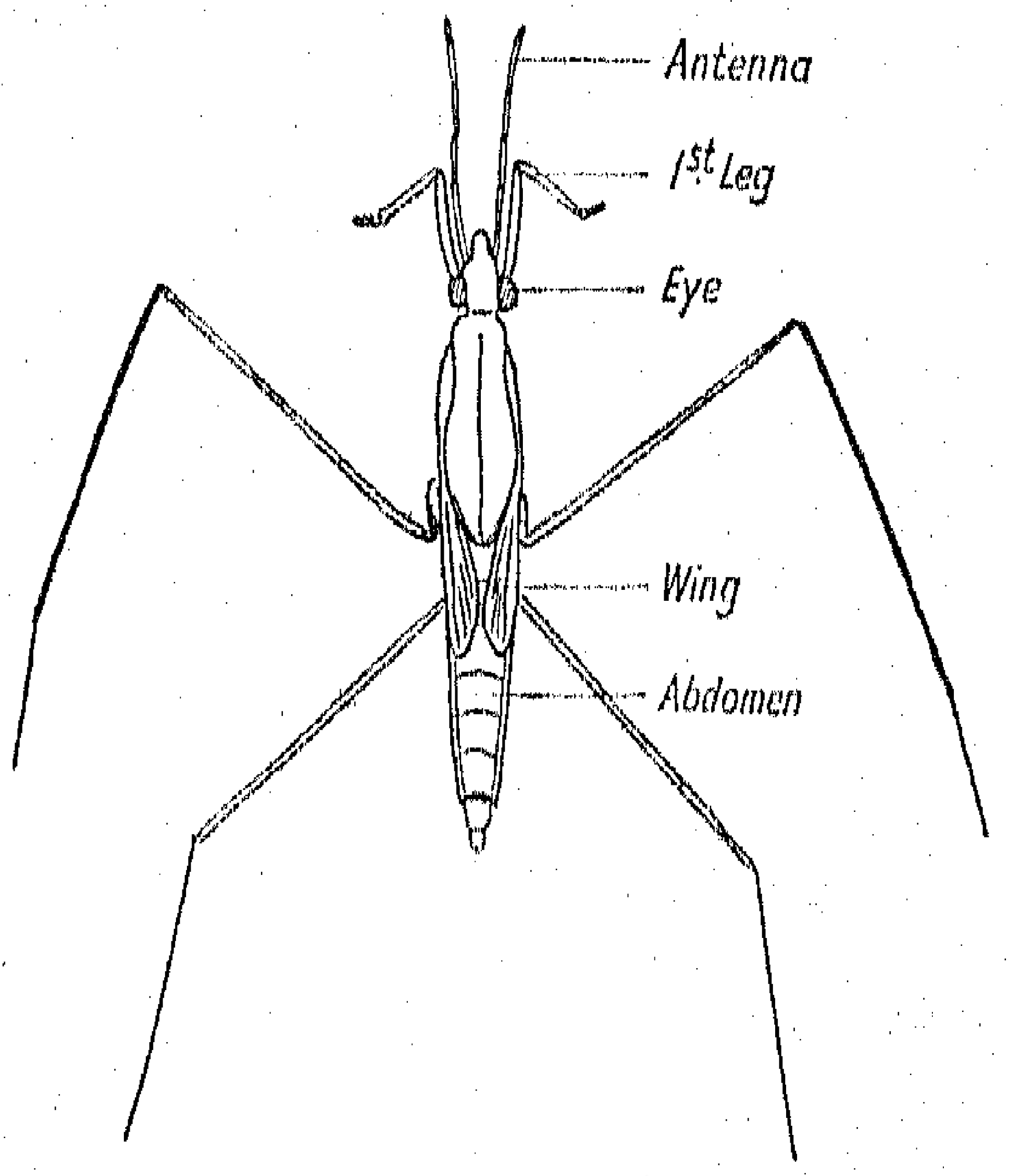


FIG. 92.—Pond Skater, *Gerris spp.*, ×4.

All the species of the other common form of water boatman, *Corixa* (kor-iks-a), are smaller than *Notonecta*, and do not swim on their backs (Fig. 91). Also the air used for breathing is held between the wings and the abdomen, and is not visible.

On the surface of the water are found other members of the *Hemiptera Homoptera*. These are the pond skaters and they move about on the surface film of the water, feeding on the bodies of dead flies. The common forms are the WATER GNAT, *Hydrometra stagnorum* (hy-dro-met-ra stag-nore-um), and the POND SKATER, *Gerris* (jer-ris) (Fig. 92).

With the exception of *Corixa*, the water bugs are all fierce, preying upon other creatures, so they must not be placed in aquaria containing small animals that you wish to keep. If you desire to make a collection of the various kinds, you can gum them on to white cardboard as with beetles; but it is more fun to keep a collection of live water bugs, in separate jam-pots.

CHAPTER SEVENTEEN

Earwigs, Grasshoppers, and their Relatives

Earwigs

THERE is some doubt how those curious insects called **Earwigs** obtained their name. Some think it is because they have in the past occasionally crawled into the ears of people sleeping out of doors on the ground, while others believe that the word is an altered form of "ear-wings". It is certainly true that each of the two hind wings is shaped rather like the outline of an ear (Fig. 93).

Earwigs are very common insects, often found throughout most of the year in both town and country gardens. Sometimes one comes across them while digging, or turning over garden rubbish. They are often to be found crawling on flowers where they damage the petals by nibbling them. Other favourite lurking places are under pieces of wood, bricks, or

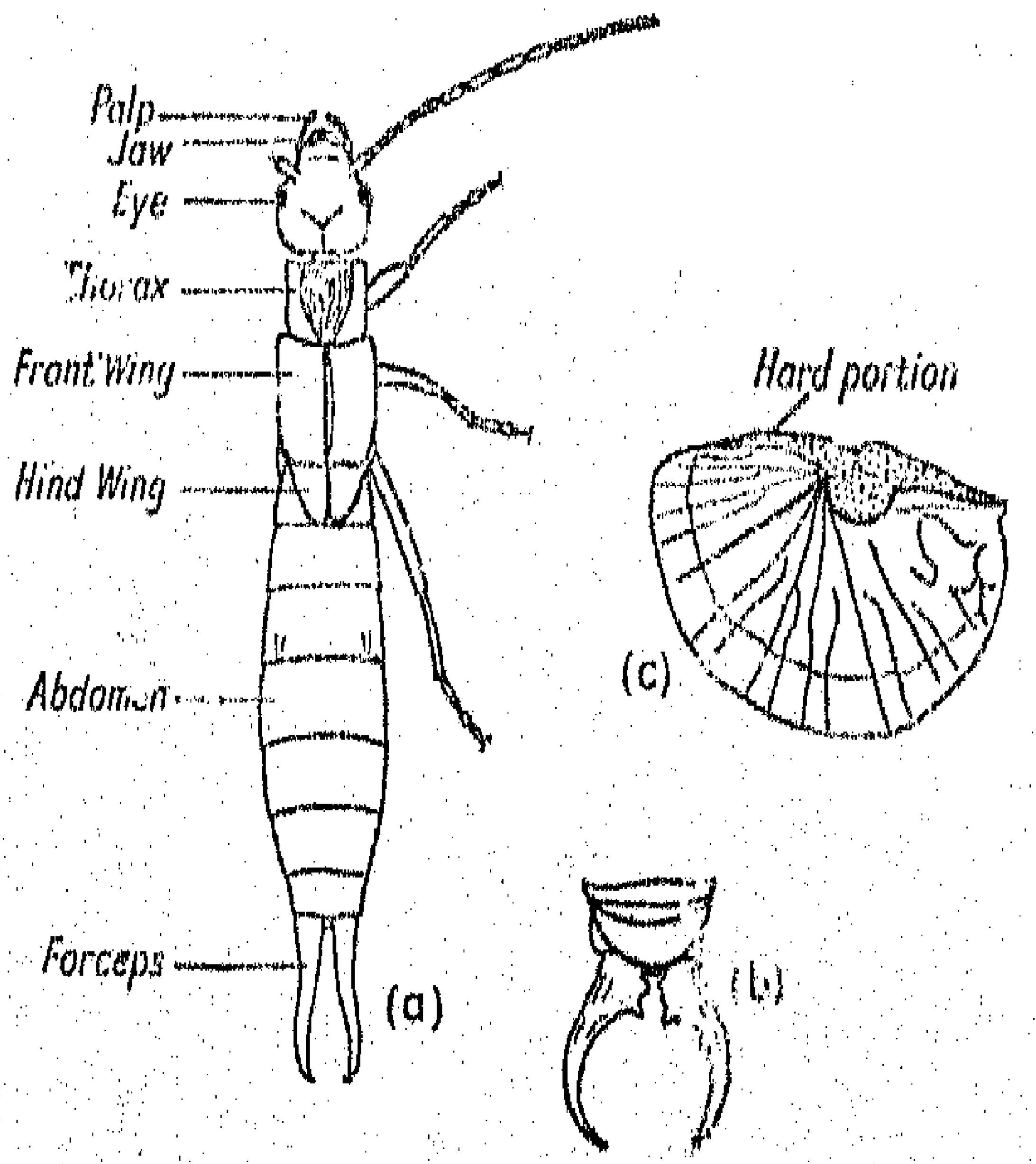


Fig. 93.—(*a*) female earwig, *Forficula auricularia*, with the legs and antenna from the left side omitted, ×4; (*b*) the forceps of a male, ×6; (*c*) a hind wing, ×6.

old sacks lying on the ground, or behind the dead bark on old trees. They hide during the day and become active at night.

In colour, earwigs are a dark mahogany shade, but the head is a lighter brown, and the wing-covers and the edges of the thorax are a pale greyish-yellow. Earwigs are about $\frac{3}{4}$ inch long, and the body is rather flattened from the dorsal to the ventral surface. The body is clearly divided into the three parts usual in insects; head, thorax, and abdomen. As there are also six legs, two pairs of wings, a pair of compound eyes, and a pair of antennæ, the earwig fits quite closely our description of a typical insect (p. 105).

The head is somewhat heart-shaped and possesses a hard outer layer of chitin. At the front end are numerous mouth-parts rather huddled together and difficult to see distinctly except for a pair of small feeler-like palps situated a little behind and to the sides of the mouth. If you look at the head through a hand lens, from underneath, you will be able to observe these palps quite clearly and see that each has three visible segments.

The compound eyes are placed at the sides of the head, just behind the middle. They are black, and almost round in outline. With the aid of a hand lens the numerous facets can easily be seen. There are no signs of any simple eyes.

The antennæ are long and threadlike, each consisting of fourteen segments. At the back of the head, on the top, is a Y-shaped groove in the hard chitin.

The head is joined to the thorax by means of a narrow neck. Viewed from above, the thorax is rather square in outline. Its side edges are nearly transparent and are drawn out into little flattened ledges which project from the body.

At the hind end of the thorax are the two pairs of wings. The front pair are rather hard and quite short. When folded, as they nearly always are, the left wing slightly overlaps the right one in the mid-line, but you will have to look closely to see this. At first sight, it looks as if the edges of these wings meet one another, as do the wings of beetles.

If you raise one of the front wings with a pin, you will find a hind wing underneath it. This is carefully folded and is very delicate and soft except for a small area along its front edge. To unravel it requires some patience, for it is folded in a rather complicated way. To spread out a hind wing you will have to remove it from the earwig. Even then it is difficult to unfold. I find it best to float the wing in a drop of water on a piece of paper and then brush it out flat by means of a paint brush. When you have one of these hind wings spread out, you will see that it is nearly semi-circular in outline and provided with very many delicate veins. At the middle of its front edge is the hardened area mentioned above (Fig. 93*c*).

When all the wings are folded, you will be able to see that the front wings are not quite long enough to cover the hind wings completely. In consequence you will be able to see a small portion of each hind wing projecting beyond the front wings (Fig. 93*a*). This portion is the hardened area in the middle of the front margin already mentioned.

It is said that earwigs very seldom use their wings for flying. Certainly I have never seen one do so. No doubt you will keep a sharp look out, in the hope that you may be more fortunate, though it is probable that if earwigs fly they do so mainly at night. If you examine the radiators of cars that have been on long night journeys, you will find many insects, chiefly moths, trapped there, but, if earwigs do fly much at night, a few of them should occasionally be present.

The three pairs of legs beneath the thorax have a normal structure. They are lighter in colour than the rest of the body. The feet or tarsi each have three segments, the last of which carries a pair of sharp curved claws.

The abdomen has a broad connection with the thorax. It is more or less parallel-sided, and ends in a pair of hard pincers. The nature of the pincers will enable you to distinguish the males from the females. In males the pincers are stout and strongly curved, and each member has a sharp pointed tooth on its inner edge where it is joined to the abdomen (Fig. 93*b*). In females the pincers are more slender and do not have the teeth, nor are they so strongly curved as the pincers of the males. In male earwigs you should be able to count nine segments on the abdomen when viewed from above, but the first segment is partly hidden by the wings and only visible at the sides. In females you will be able to count only seven segments. It is worth while to examine the sides of the abdomen, to see the manner in which the plates forming it overlap one another.

It is believed that the pincers are used to fold the wings after flight, and are probably used also for attack and defence, because an earwig that is alarmed will hold its tail up with the pincers opened widely in a threatening manner. In spite of this, however, it seems very reluctant to close them on one's fingers or even on a matchstick held between them. Some observers have seen earwigs use their pincers to hold flies they have caught, and earwigs certainly use their pincers to help themselves to turn over, if they happen to fall on their backs.

Not much is known about the food of earwigs, though they seem to eat a variety of substances, both vegetable and animal. Probably they eat other insects, and possibly small snails and slugs. Keep a few earwigs in a large tin or box with some damp soil and experiment with different foodstuffs.

Earwigs lay their eggs in the soil, and in other places, during early spring, and the female watches over them until they hatch.

Early in April I discovered a female earwig together with forty-two pale yellow eggs under a piece of bark on an old tree stump. I placed her, together with the eggs, in a specimen tube. The eggs were all jumbled together, and some time later I was surprised to find them collected into a neat pile. I disturbed the eggs again and watched to see what the earwig would do. After a short time she began to pick up the eggs in her jaws and carry them to make a new pile. She did this as often as I disturbed the eggs. Next, I scattered the eggs throughout some soil on a saucer, covering the soil with a tumbler. In the morning the eggs had been collected again, and the earwig was standing over them as usual. The eggs took nearly five weeks to hatch, and, for some days before they did hatch, the young earwigs inside could be distinctly seen. The newly hatched earwigs clustered under the mother, reminding me strongly of chickens under a broody hen.

Except for a few small differences in structure, the young earwigs, when they hatch, are very like the adults, but are lighter in colour and the body skin is not so hard. They moult several times, increasing in size at each moult, and so gradually turn into adults. Immature earwigs are often turned up when one is digging in the garden during early summer, and are easily recognised by their pale creamy colour.

Earwigs can be killed in a laurel-bottle or in hot water, and set with gum tragacanth on white cardboard, in the same way as beetles. It is instructive to collect a good number and make careful drawings of the male pincers. They will be found to vary considerably in shape and size.

Grasshoppers and their Relatives

Probably most of you are familiar, in a general way, with those insects we call grasshoppers. Fig. 94 is a drawing of one of the commonest SHORT-HORNED GRASSHOPPERS, and the drawing makes clear the main points of the structure.

The head is fixed to the thorax without any signs of a neck. It is much deeper (i.e., from forehead to chin) than it is long, and the front of the face slopes distinctly backwards. The mouth parts occupy the lower third of the face and, in addition to the biting jaws, you will be able to see two pairs of jointed palps. There is a pair of very prominent compound eyes, and situated on the forehead in front of these, a pair of threadlike antennæ. Each antenna has numerous small segments (about twenty-two in the species drawn).

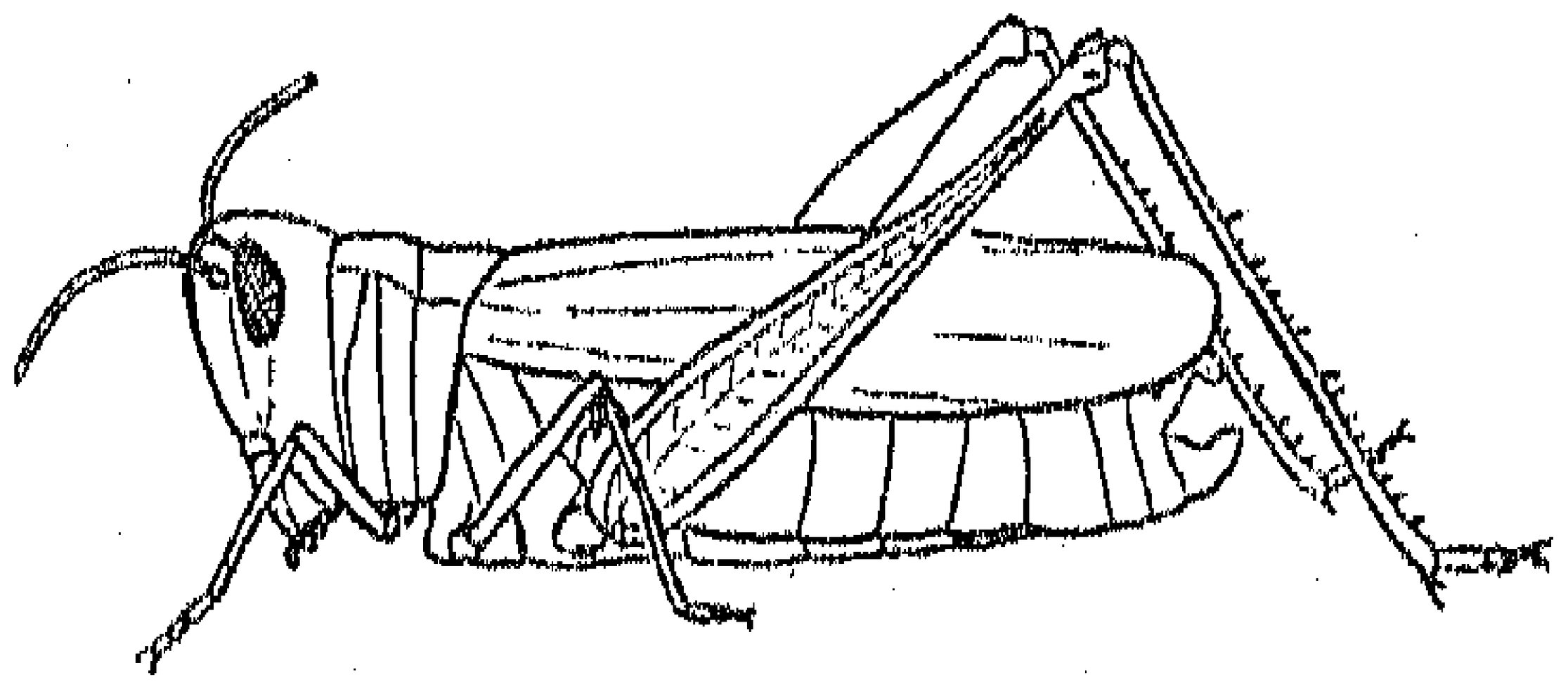


FIG. 94.—Short-horned Grasshopper, *Chortohippus bicolor*, ×2½.

The thorax is composed of a number of plates and, like the head, is deeper from top to bottom than it is wide from side to side. Its various walls are more or less flat. It carries three pairs of legs and two pairs of wings, though in some species the hinder pair of wings may be very small or absent altogether.

The legs consist of the segments usual in insects, but each tarsus has only three segments. The end segment carries a pair of claws with a fleshy pad in between them. These structures can be only just discerned with the naked eye but are easily visible under a hand lens. The last pair of legs is remarkable for the manner in which the femurs are enlarged and swollen. Contained in these swollen femurs are the muscles which enable the grasshopper to jump so vigorously.

When the grasshopper is not flying, the wings are folded along its back. The first pair of wings are rather horny, and are called elytra (as in beetles). They are long and rather narrow, with a complicated network of veins. Folded under the elytra are the second pair of wings. These are more delicate and, when unfolded, are seen to be much broader and rather triangular in shape. They, also, have an elaborate network of veins.

The abdomen is stout and rather parallel-sided. The plates which compose its surface can be distinctly seen, and nine segments can be counted at the sides. At the end of the abdomen are the genital structures.

Male grasshoppers are capable of making a chirping noise, but the females usually cannot produce any sort of sound. In the species drawn in Fig. 94, *Chortohippus bicolor* (kor-toh-hip-pus by-kol-or), the sound is produced by rubbing the inner face of the femur against the thickened lower edge of the elytron. On the inner face of each femur is a row of about 90 tiny peg-like projections, and, as these scrape over the elytron, the latter is set vibrating to give the familiar chirping sound. You can imitate this action by scraping a pencil or matchstick across the teeth of a comb.

When animals are capable of making a sound, we usually find some kind of ear also present. This is so with the short-horned grasshoppers, where the ears are situated on the first segment of the abdomen. There is one "ear-drum" on each side, and it can be seen on the body wall above the base of the third pair of legs. Each drum is in a depression which is surrounded by a horny ridge.

The colour of the species drawn varies a good deal, but the ground colour is usually brownish green and the tip of the abdomen red. This insect is widespread and quite common.

Female grasshoppers lay their eggs in the ground. The holes for the eggs are made by means of the stout horny valves of the ovi-positor (egg-layer). Usually several holes are dug over a period of some weeks, and in each, between 30 and 100 eggs are laid. The female pours a fluid over the eggs, which hardens to form a waterproof covering.

Egg-laying takes place in August and sometimes in September, but the eggs remain in the soil throughout the winter, not hatching until May of the following year. The young grasshoppers are called *nymphs* and have the general shape of the adults, although as yet there are no signs of the wings. The nymphs feed on plant matter and grow rapidly, moulting a number of times. At each moult they become even more like their parents. The wings appear after the third moult and grow larger at each following moult until, about July, they are fully formed and the insects are adult.

This kind of growing up is called direct development. There are none of those profound changes in form known as metamorphoses (met-a-morf-o-seez), such as are found in the development of butterflies and mosquitoes, whose larvæ change abruptly into pupæ and the pupæ into adults.

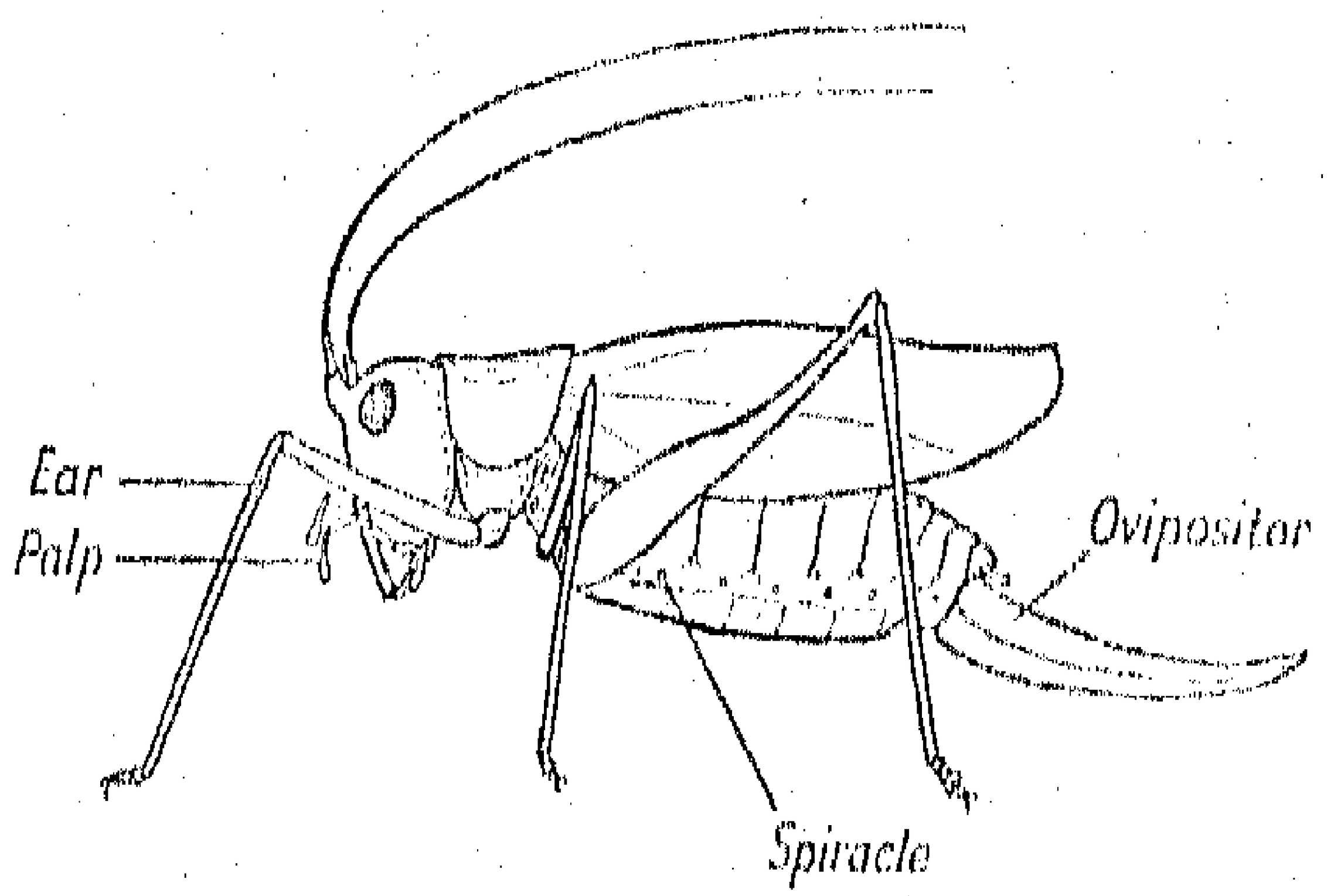


FIG. 95.—Long-horned Grasshopper, *Meconema thalassina*, female, ×2½.

The Locusts, which are such plagues in certain warmer countries, are short-horned grasshoppers, as also are the ground hoppers. The latter are smaller than the grasshoppers and are always brown in colour. Their most obvious difference is that the top of the thorax projects backwards as a kind of roof over the abdomen.

Closely resembling the short-horned grasshoppers are two other groups of insects. These are the long-horned grasshoppers and the crickets.

The long-horned grasshoppers (Fig. 95) have threadlike antennæ with more than thirty segments. These antennæ are about as long as the body, or in some species, even longer. The body colour is usually a bright green and the chirping noise is made by rubbing the elytra together, not, as in short horned grasshoppers, by rubbing the femurs on the edges of the elytra. The "ears" in long-horned grasshoppers are on the front tibiæ near their junctions with the femora. The ovipositor is curved and flattened from side to side, and the tarsi have four segments, whereas they have only three in short-horned grasshoppers.

The crickets (Fig. 96) also have long antennæ, but the tarsi in this group have only three segments. Like the long-horned grasshoppers, crickets make their chirping noise by rubbing the elytra together, and the "ears" are on the front tibiæ. The ovipositor is straight and needle-like.

Here is a key that will help you to determine to which of the above four groups a particular grasshopper-like creature belongs.

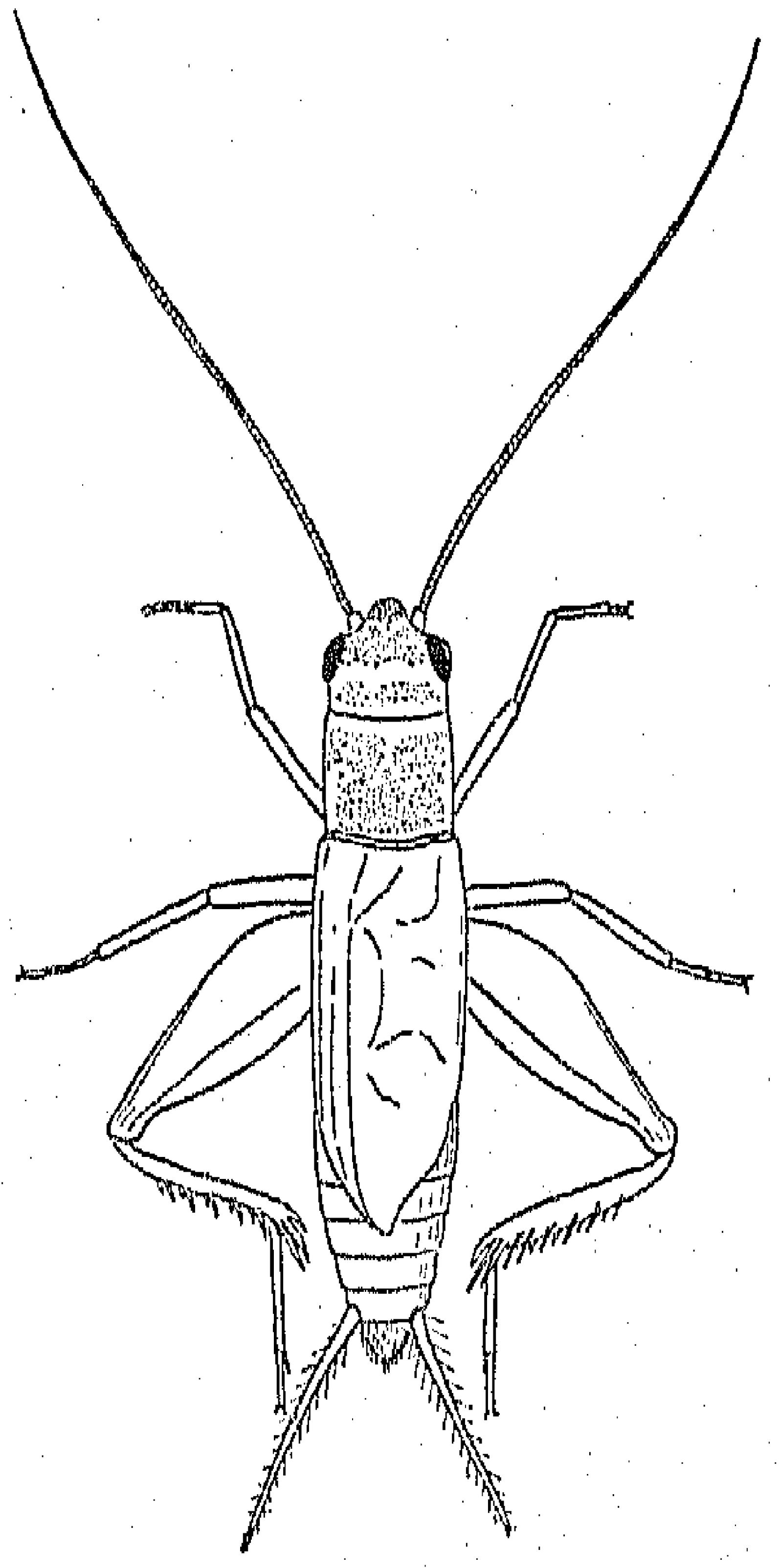


FIG. 96.—House Cricket, *Gryllus domesticus*, ×2.

KEY TO THE GRASSHOPPERS

1	Antennæ less than half as long as the body; the hind femurs with prominent ridges or keels, their edges drawn out into obvious ridges	2
	Antennæ more than half as long as the body; edges of hind femurs smoothly rounded	3
2	Top of the thorax produced backwards to cover the abdomen; each tarsus without a pad between the claws; brown in colour	GROUND HOPPERS
	Top of the thorax not produced backwards to cover the abdomen; each tarsus with a pad between the claws	SHORT-HORNED GRASSHOPPERS
3	Tarsi with three segments	CRICKETS
	Tarsi with four segments	LONG-HORNED GRASSHOPPERS

Grasshoppers are best caught by sweeping a net in grass or other low-growing herbage. They may be killed in a laurel-leaf bottle, and kept on pins in a dust-proof box; but the colours soon fade. If dried specimens become loose on their pins they may be fixed with glue.

If you obtain a live grasshopper, take it on to a wide stretch of concrete or other clear ground and make it jump by touching it. Observe the height and distance of its leap. If you make it jump five or six times in succession, you will find that its leaps become feebler and feebler until it can no longer move. Its muscles are, for the time being, completely exhausted. After a short time, it will be able to jump again.

This power of jumping is very useful to a grasshopper, for, when danger threatens (e.g., from a bird), it can leap away to a considerable distance; it is then very difficult to find because usually its colour is fairly similar to its background. The general body shape also aids concealment.

CHAPTER EIGHTEEN

Dragonflies

THE DRAGONFLIES form a very distinct order of the insect class. They are among the largest of the British insects and have a very characteristic shape (Fig. 97). As the adult dragonflies do not differ greatly, except in colour and size, I shall give a general account, because it is not always easy to catch a particular species.

The head is large with a pair of relatively enormous compound eyes and three simple eyes. The antennæ are very thin

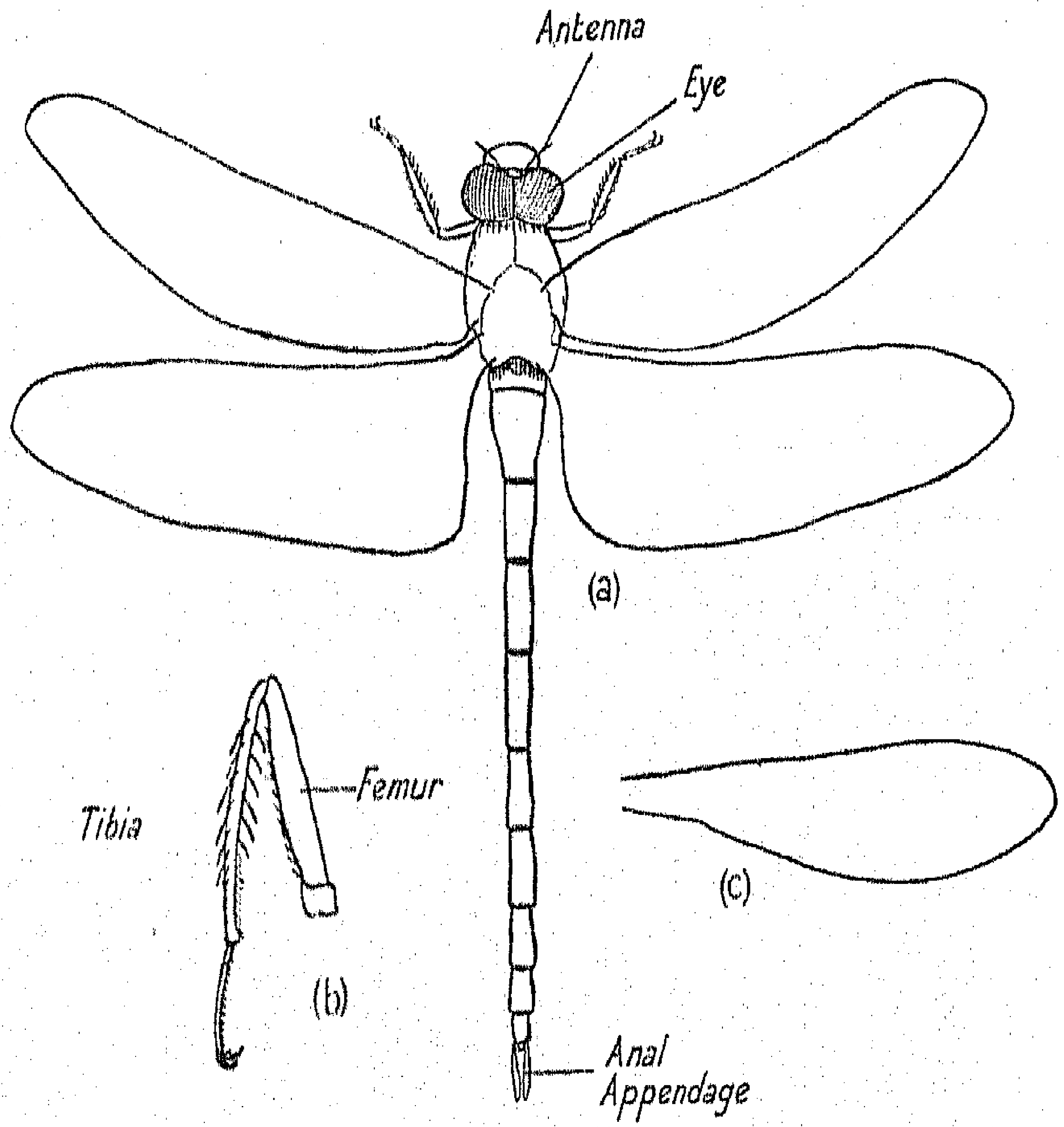


FIG. 97.—Dragon-fly, × 1; *left*: a front leg, × 3; *right*: outline of wing of damsel fly.

and quite short. Probably they have but little importance as sense organs.

The general arrangement of the various parts of a dragonfly is shown in Fig. 97. The head is fixed by a slender neck to the stout thorax, which bears two pairs of prominent wings and three pairs of legs. The fore and hind wings are rather like one another and the network of veins is very complicated indeed. The pattern of the veins is slightly different in the various kinds of dragonflies and is used by experts to distinguish one species from another.

The wings provide a means by which we can divide dragonflies into two distinct sub-orders—the dragon-flies proper and the damsel flies. Note that when the sub-order *dragon-flies* is referred to, the word is spelt with a hyphen, but when the whole order is meant, both dragon-flies and damsel flies, we spell the word without a hyphen, *dragonflies*.

The damsel flies are smaller than the dragon-flies and they have a rather slow flitting flight. In addition, their fore and hind wings are very like one another and taper gradually to the base (Fig. 97*c*). When at rest, damsel flies fold their wings together above their backs in the same way as butterflies. The dragon-flies are bigger and stouter than the damsel flies, fly much faster, and their fore wings are somewhat different from their hind wings. The wings are broad right down to their bases, the hind wings being actually widest near the base. The hind wings also have a little border of opaque skin along the edge nearest the body. When at rest, dragon-flies spread their wings out sideways like the wings of an aeroplane.

There is nothing unusual in the shape of the six legs, but each is provided with a double row of stiff spines which are believed to help in capturing food (Fig. 97*b*). The abdomen consists of ten segments, of which the first and the last are rather short. The last abdominal segment bears structures called the anal appendages.

Dragonflies live entirely on other insects, which are caught on the wing or else snatched from flower heads and other places by the dragonflies as they skim past. They catch especially large numbers of mosquitoes and gnats, though the larger kinds catch bigger insects such as wasps and bees, and apparently sometimes even smaller dragonflies.

The males can be distinguished from the females by the presence of a *mating pouch* under the 2nd and part of the 3rd abdominal segments. Here the male sex cells are stored. When two dragonflies are mating, the male seizes the neck of the female with his anal claspers and the female bends the tip of her abdomen round so that it comes into contact with the mating pouch of the male. Very often two dragonflies, especially damsel flies, may be seen flying along coupled together in tandem fashion (Fig. 98). The female is always the hinder one of such a pair.

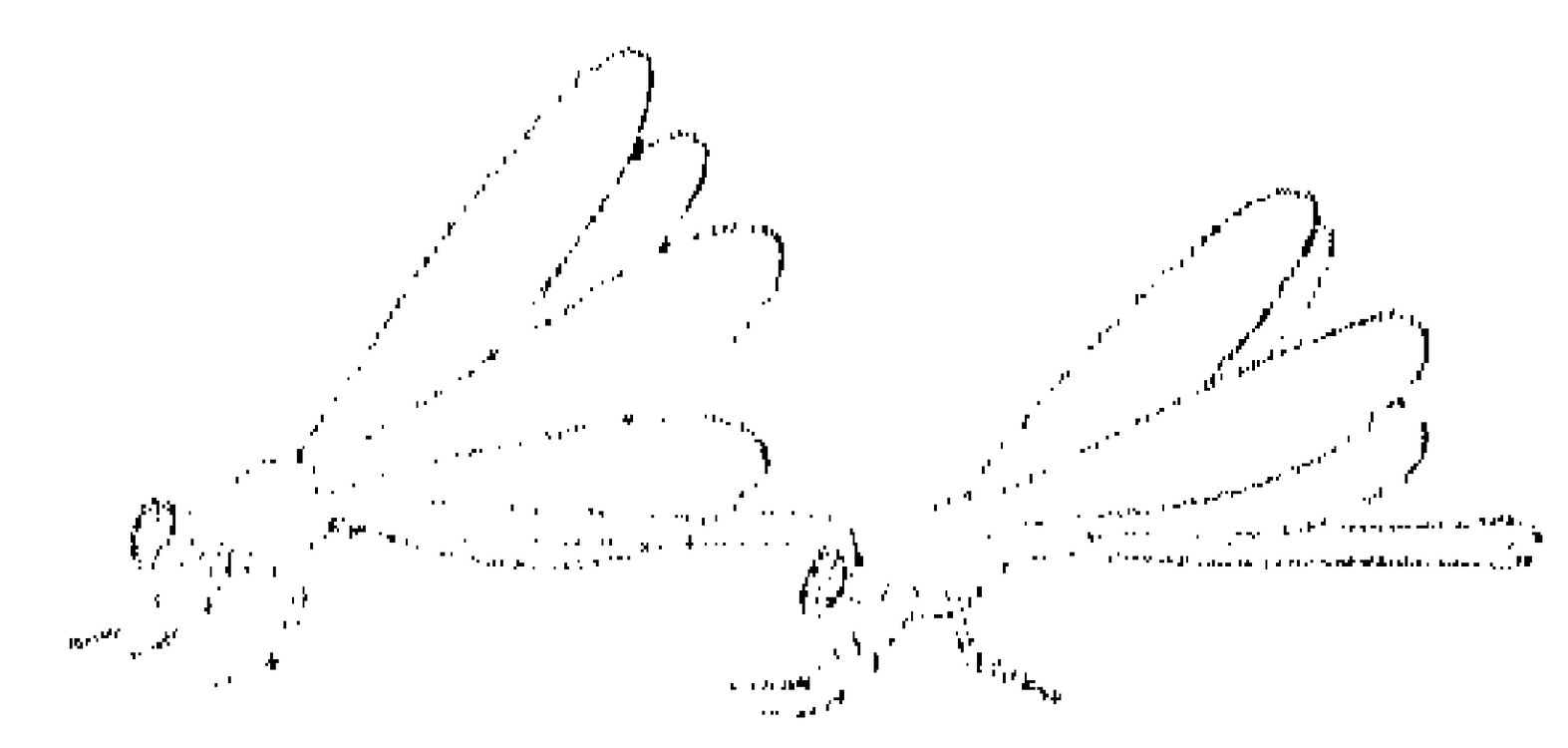


FIG. 98.—Damsel flies flying in tandem during mating. The male is in front, × 1.

The eggs are laid either on the surface of water or on water plants below the water. Some species actually make holes in the stems of water plants and lay their eggs in these.

The eggs hatch into nymphs which feed on other water animals. The nymphs may moult as many as twelve times before they reach the adult stage, and the underwater life of the nymphs may take one or more years.

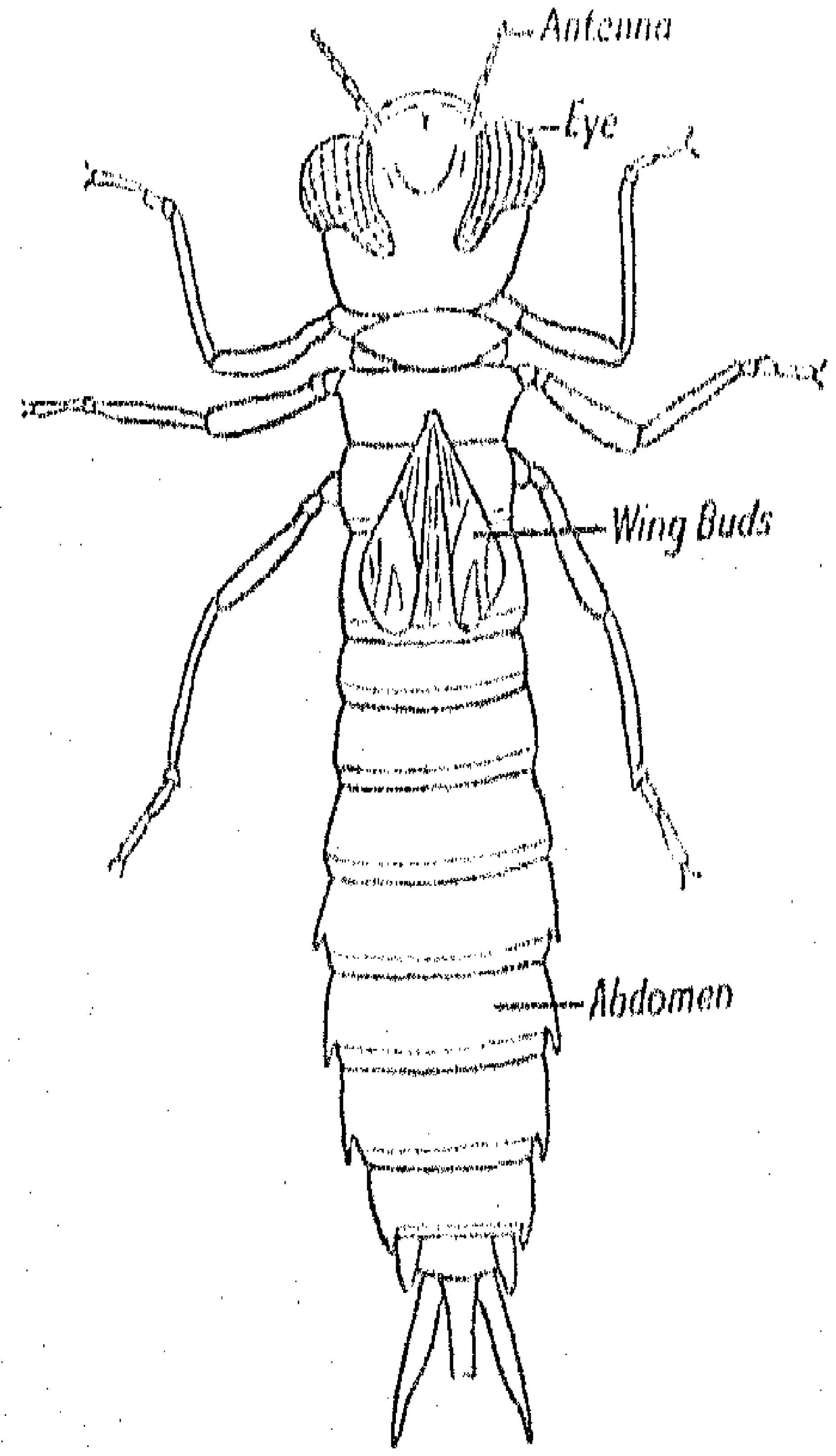


FIG. 99.—Nymph of *Aeschna* dragon-fly, × 1½.

A dragonfly nymph is a curious creature. The young nymphs differ somewhat from the older ones and have no visible trace of wings, but, as they are rather small, I will describe an older nymph just before it is ready to turn into an adult dragonfly.

The nymphs of the various dragon-flies each have their own particular shapes, but the general pattern is the same. The body is divided into head, thorax, and abdomen; in colour is generally muddy brown, or green with darker markings; and is rather flattened from the dorsal to the ventral surface. The head has a pair of bulging compound eyes and a pair of rather thin antennæ. Below the mouth is a curious structure called the "mask" which really represents the bottom lip. The mask consists of a two-jointed piece of chitin fixed to the head at one end and carrying a pair of sharp pincers at the free end (Fig. 100). When a small moving creature (e.g., a small fish or tadpole) passes near the nymph, the mask is suddenly shot forwards and the fangs of the pincers driven into the prey in order to grasp it firmly. Then the mask is withdrawn to bring the prey opposite to the mouth, where it is rapidly devoured.

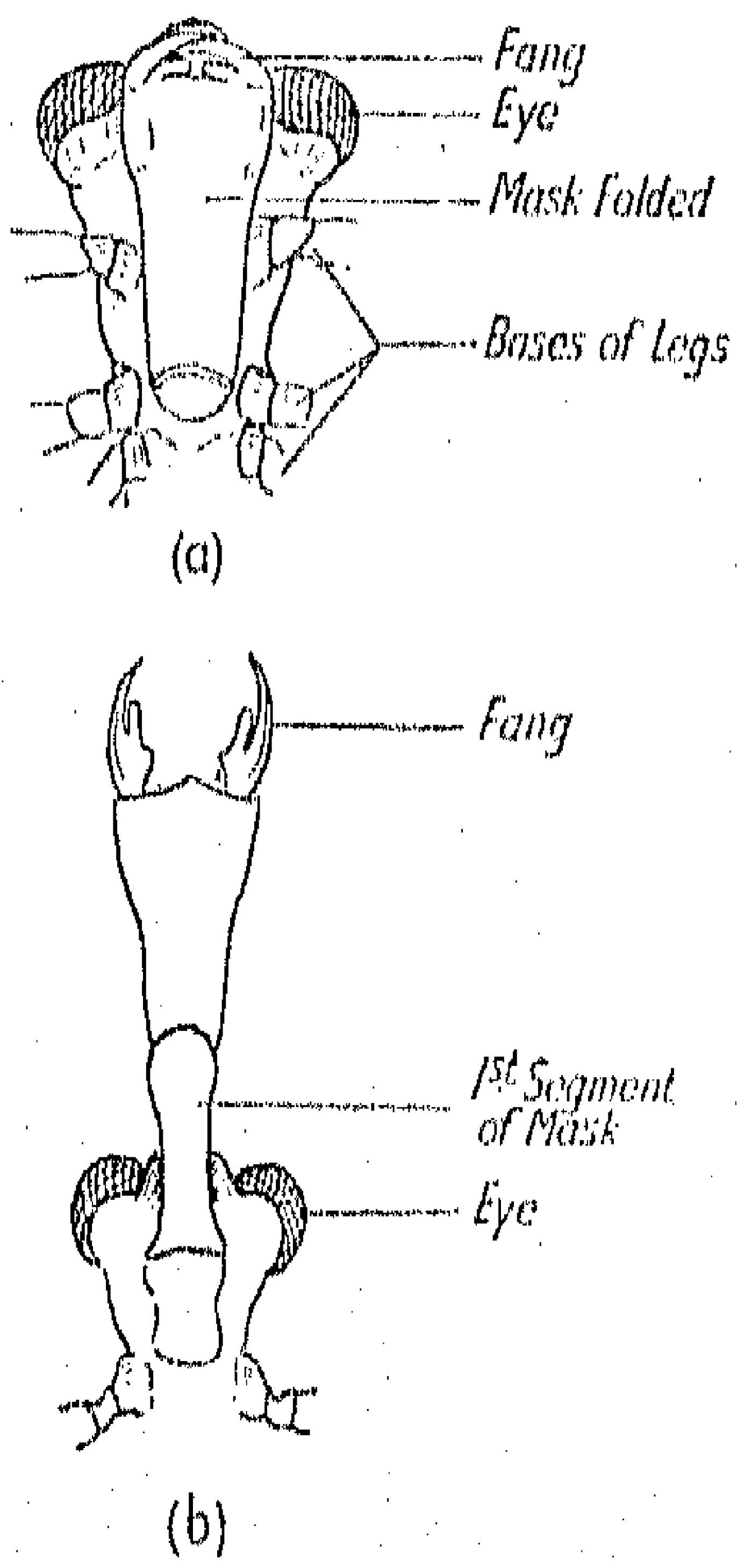


FIG. 100.—(*a*) head of damsel fly drawn from below to show the mask in its resting position; (*b*) the mask extended. [(*a*) ×4, (*b*) rather less.]

On the thorax of the nymph are three pairs of legs which are used for walking, each leg having a pair of tiny claws at the free end. The first stages of the wings are flap-like out-growths on the dorsal surface of the thorax.

The abdomen is segmented and bears at its hind end five short processes. Two of these, at the sides, are very small, so there may appear to be only three (Fig. 99).

The damsel fly nymphs are rather different in appearance, being much more slender in the body. At the hind end of the abdomen there are three flattened processes which are quite long and form part of the breathing equipment (Fig. 101).

When the nymphs are full-grown, they crawl up the stems of water plants into the air. Here the skin splits along the back and slowly the adult dragonfly struggles out. Its wings at first are small and crumpled, but they are soon pumped up by blood forced into them through the veins. The body also expands. In two or three hours the insect has become a typical dragonfly, and, its tissues hardened by exposure to the air, it is ready to fly away.

Adult dragonflies may fly very far from water, but they return to it to breed, and usually in summer you will find plenty of dragonflies darting about near most stretches of water, particularly on hot days.

The nymphs are easily obtained with a pond net and the bigger ones are not difficult to keep in aquaria. They must be fed, and this is sometimes difficult as they prefer moving prey. The larger ones readily eat tadpoles, and will sometimes eat ordinary fly maggots (gentles). They will eat raw meat, especially if a small piece is tied on to a piece of cotton and drawn slowly along in front of them. (*Note:* Pieces of raw meat must not be left in aquaria, or the water will become foul.)

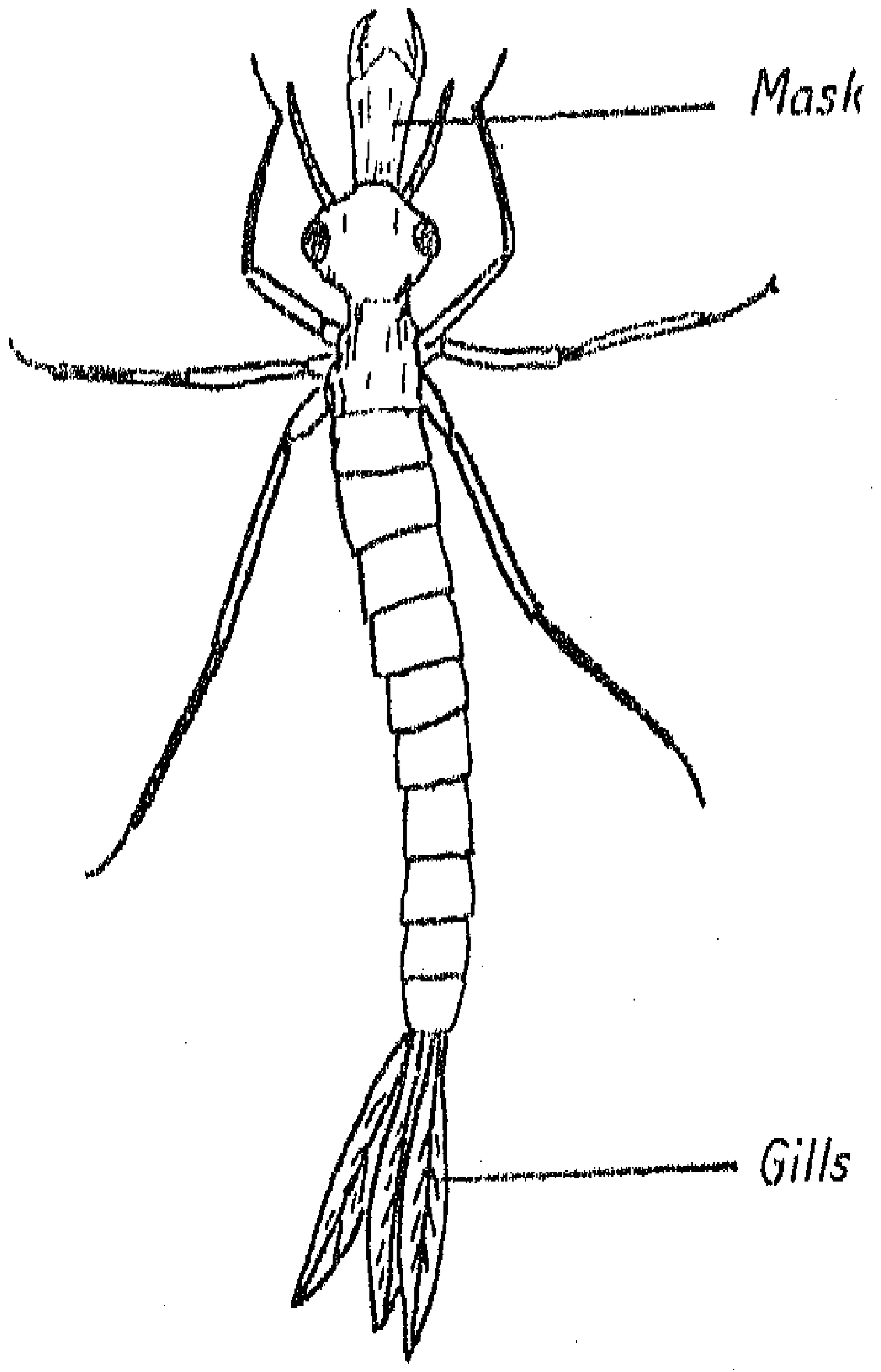


FIG. 101.—Early damsel fly larva, before the wing rudiments have appeared, ×6.

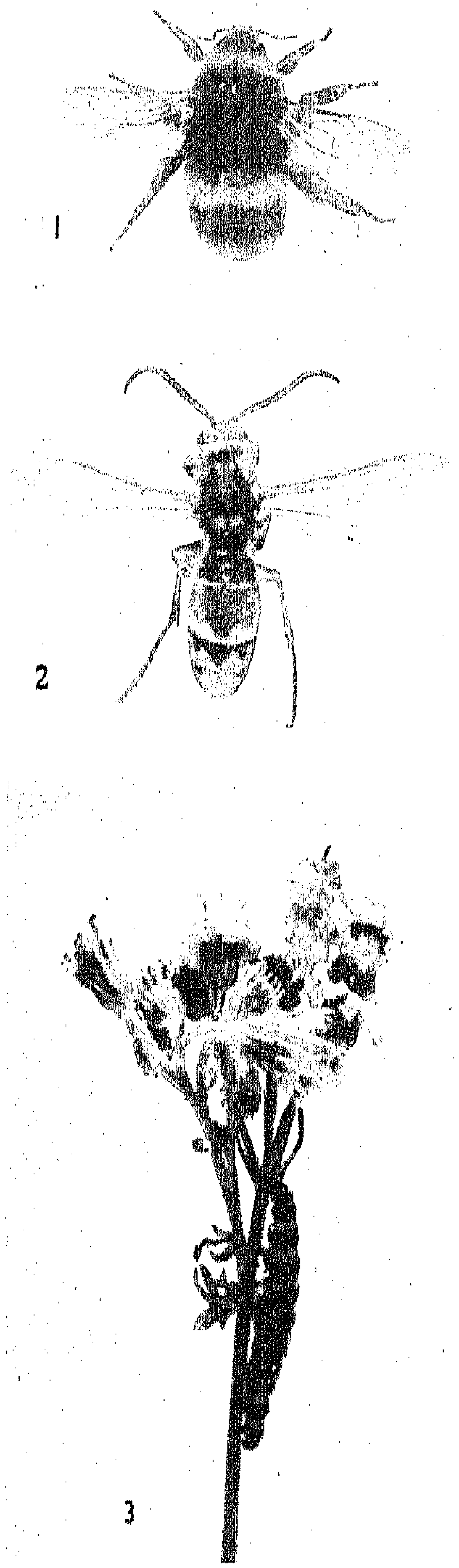
If you wish the nymphs to change successfully into dragonflies, you must provide them with something up which to climb. A piece of stick weighted at one end with a stone or piece of lead is quite suitable.

Dragonflies can be caught with a butterfly net, but as some of the larger ones can fly at 15 miles an hour and also have very keen eyesight, their capture is not always easy. Dragonflies can be set on pins on ordinary setting boards like butterflies (Fig. 74), but the colours lose their brilliance shortly after death, and some of the colours disappear completely.

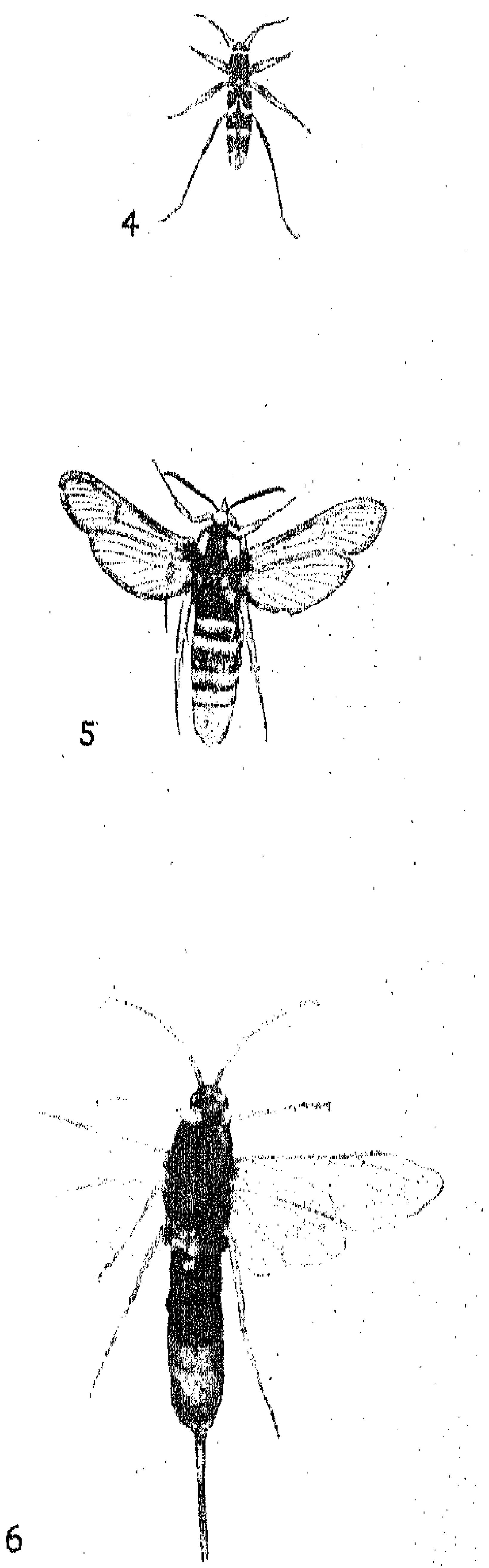
It is interesting to make a collection of the wings of the various species. After you have detached the wings from the body, one pair (i.e., fore and hind wing from one side) can be mounted on white cardboard with gum tragacanth. You may perhaps like to ponder whether the small differences in the vein patterns of related dragonflies are of any importance in the struggle for existence.

PLATE VII

Warning and Mimetic Coloration



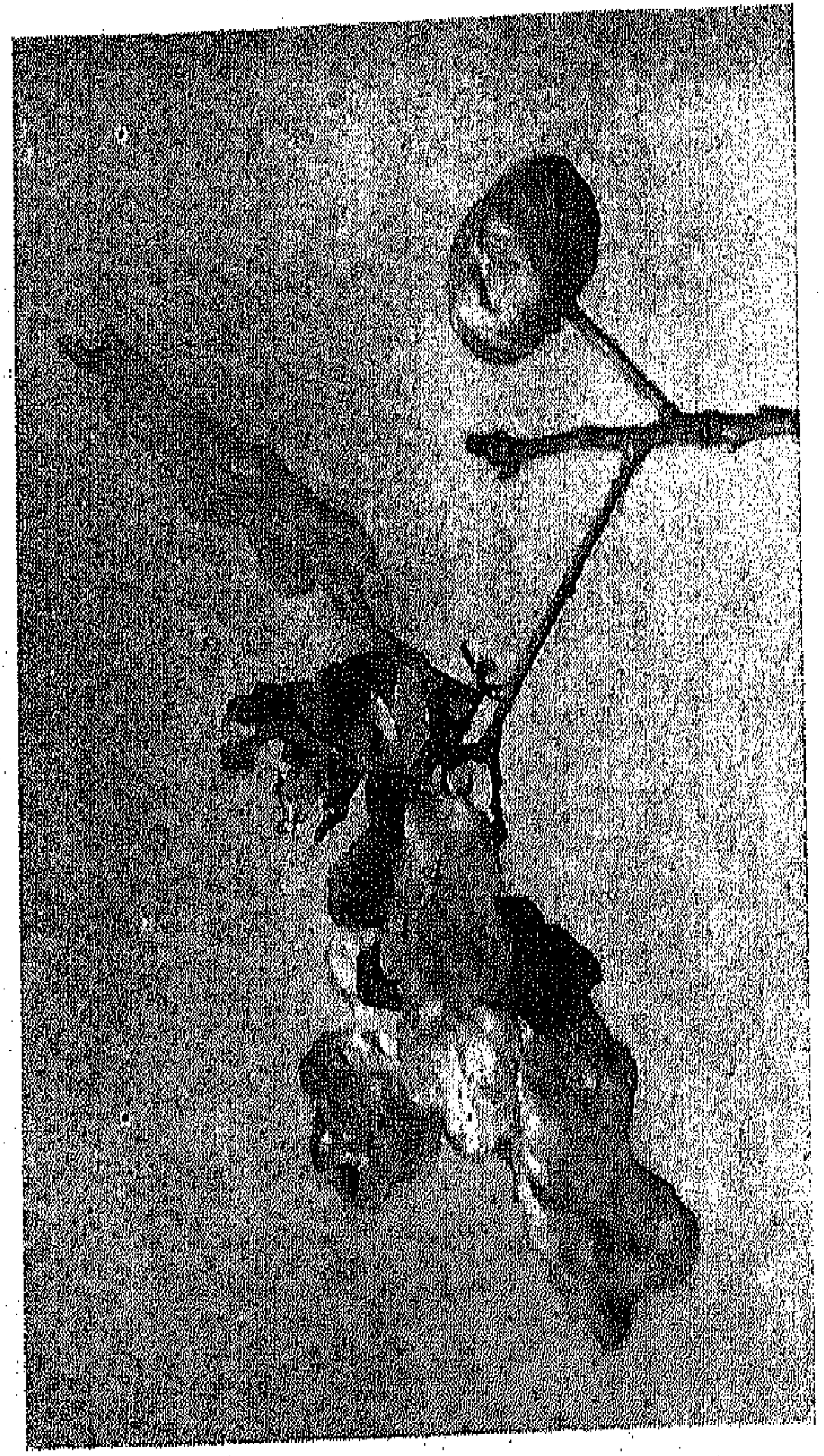
A.—Three insects which are dangerous or unpleasant to eat:
(1) A Buff-tailed Bumble Bee.
(2) A Hornet.
(3) A Cinnabar Moth Caterpillar descending from Ragwort.
The first two can inflict painful stings, the last is refused by hens.



B.—Three insects which are not dangerous, although they show typical warning coloration:
(4) The Wasp Beetle (*Clytus arietis*).
(5) The Hornet Clearwing Moth, mimicking a hornet.
(6) A female Wood Wasp (*Sirex gigas*).

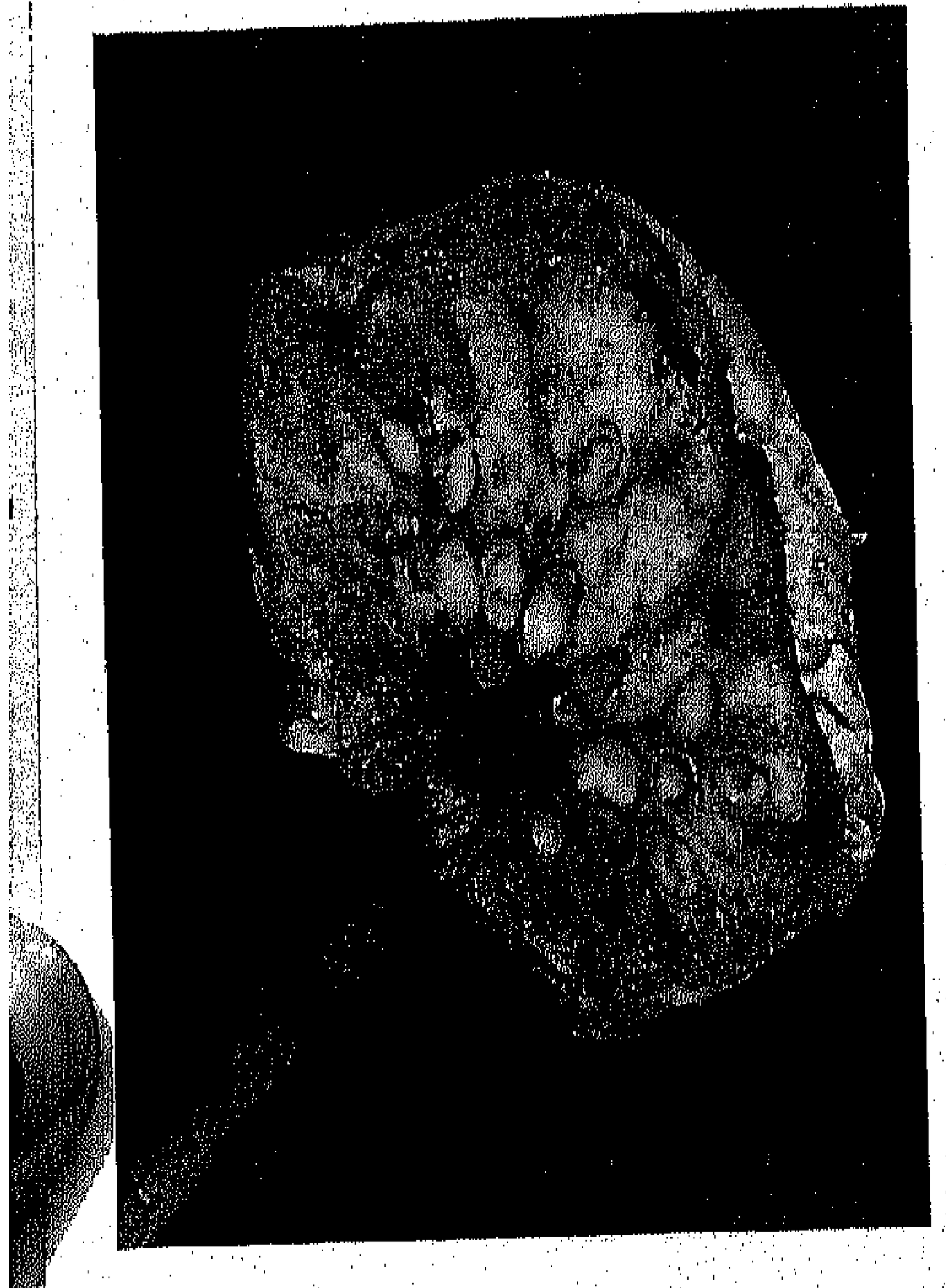
PLATE VIII

OAK GALLS



A.—An Oak Apple

B.—A Marble Gall.



C.—An Oak Apple in cross-section, to show the maggots in their chambers.

D.—Cherry Galls.

(*All reduced.*)

CHAPTER NINETEEN

Spiders

SPIDERS are frequently confused with insects, although they are quite different and very easy to distinguish.

In gardens and similar places, particularly at the end of August and during September, you may find the very beautiful webs of the GARDEN SPIDER, and the spider herself is usually near at hand. Sometimes she—for it is the females which build the big webs—is to be found hanging motionless in the centre of the web, but at other times she may be hiding nearby under a leaf or in some other sheltered spot.

It is quite easy to catch one of these spiders, for when alarmed she always drops downwards, so that if you bring a small tin up towards one from underneath, she will drop into it.

To examine the spider alive, shake it out on to a piece of white paper and cover it with an inverted tumbler. Note how it moves and how the two hind legs are dragged along. You should be able to see eight legs (four pairs) as well as a pair of smaller leg-like structures, the *pedipalps*, at the head end. These are used as sense organs. Notice that there are no antennæ in spiders, and no traces of wings (Fig. 102).

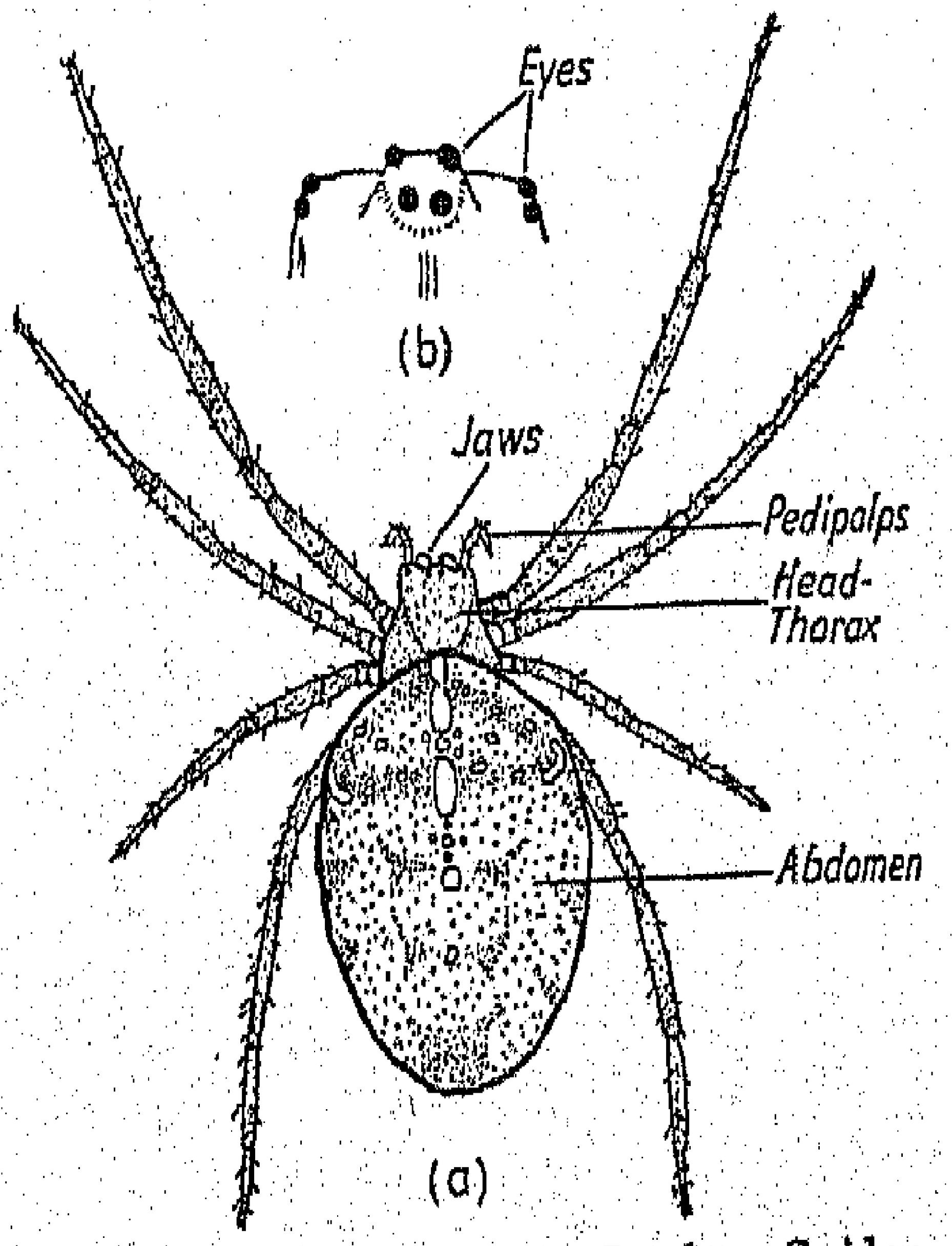


FIG. 102.—(*a*) female Garden Spider, *Epeira diademata*, from above, ×2; (*b*) magnified view of the forehead, to show the eyes.

To study the finer points in the structure of the spider, you will need a dead specimen. Spiders may be killed in the laurel-leaf killing-bottle, but take longer to die than most insects.

The body of the Garden Spider is sharply divided into two parts, the big bulging abdomen at the rear, and an anterior part which is made up of the head and thorax firmly joined together. (In insects, remember, the head and the thorax are more or less separate.) The abdomen overhangs the head-thorax, to which it is connected by a quite narrow "waist" (Fig. 103). The colour of the abdomen is a warm brownish grey, but there is also a number of white spots arranged sometimes, but by no means always, to form a conspicuous cross, which is the reason that this spider is frequently called the Garden Cross Spider.

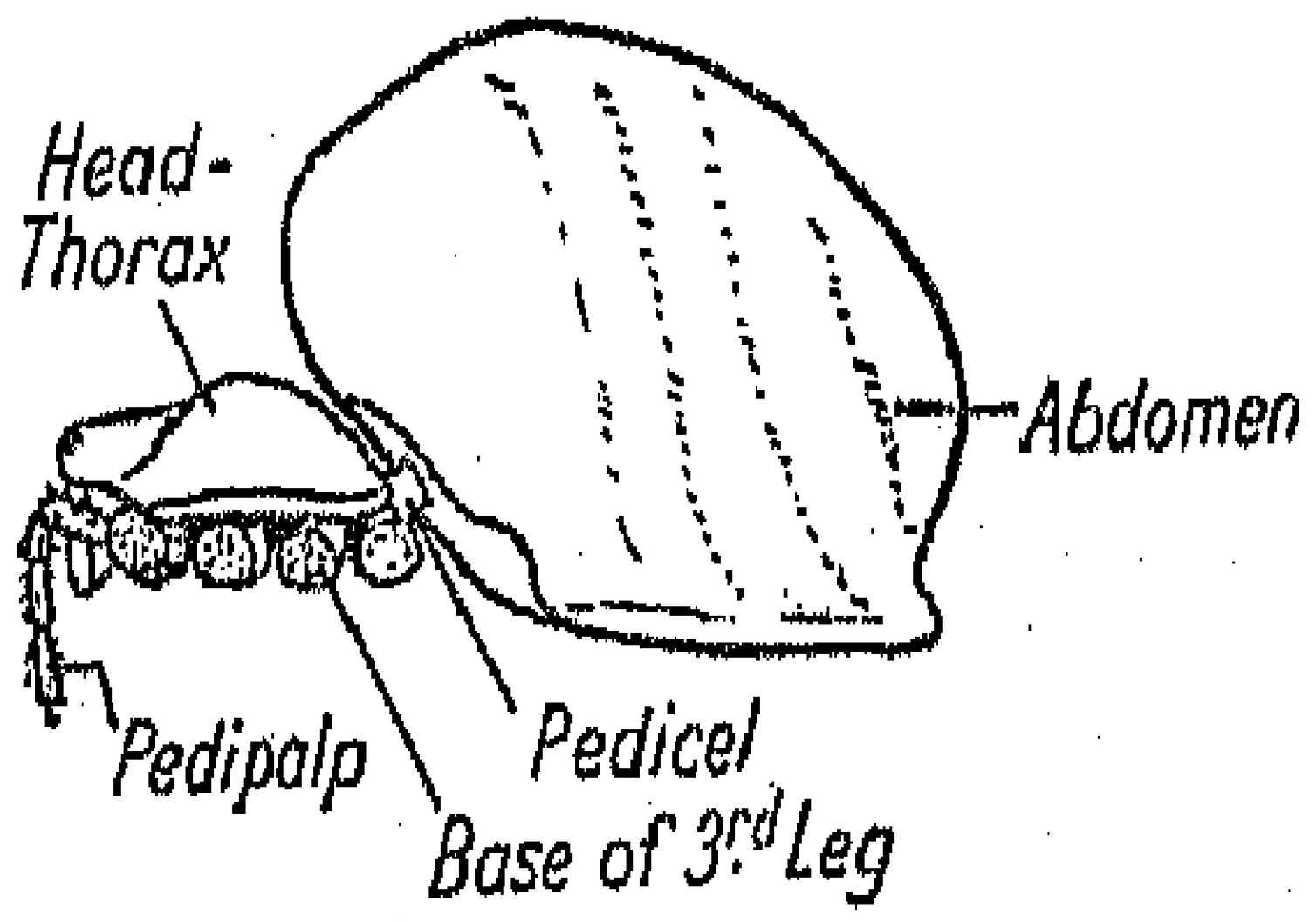


FIG. 103.—Side view of female Garden Spider, with the legs removed, ×2.

There are four pairs of legs, which are fixed under the head-thorax around the sides, leaving a central breast plate (Fig. 106*b*). Each leg is composed of seven segments which are not all the same length, and is covered with stiff hairs pointing towards the leg tip. The legs are marked with alternating light and dark bands. Right at the tip of each leg you will be able to see with a hand lens two tiny curved claws. The third pair of legs is the shortest, a character shown by all the spiders belonging to this genus, *Epeira* (ep-e-ira).

There are no large compound eyes such as are present in insects. Instead there are eight simple eyes arranged along the top front edge of the head. The head is rather square in outline when seen from above, and at each front "corner" there is a pair of eyes. The other four eyes are in the middle of the forehead and are situated on a slight swelling. Fig. 105 will make the arrangement clear. You can easily see the eyes with a hand lens: they look black and shiny.

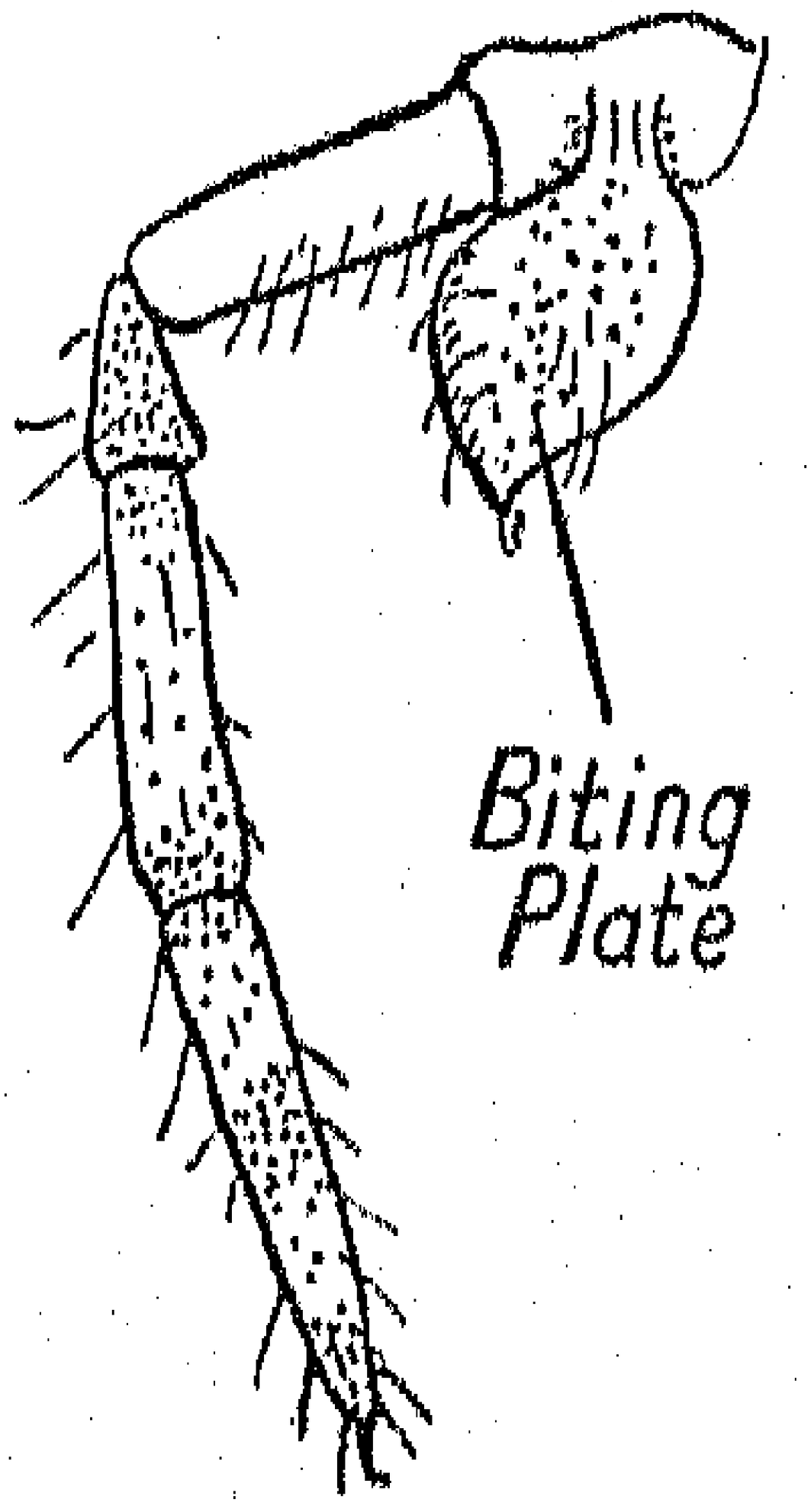


FIG. 104. — Pedipalp of the female Garden Spider ×10.

The pedipalps are the small leg-like structures near the front of the head, one on each side. Each pedipalp is composed of five segments, and is used as a feeler, probably doing most of the work that is done by the antenna of an insect. The segment nearest the body is hard and acts as a jaw (Fig. 104).

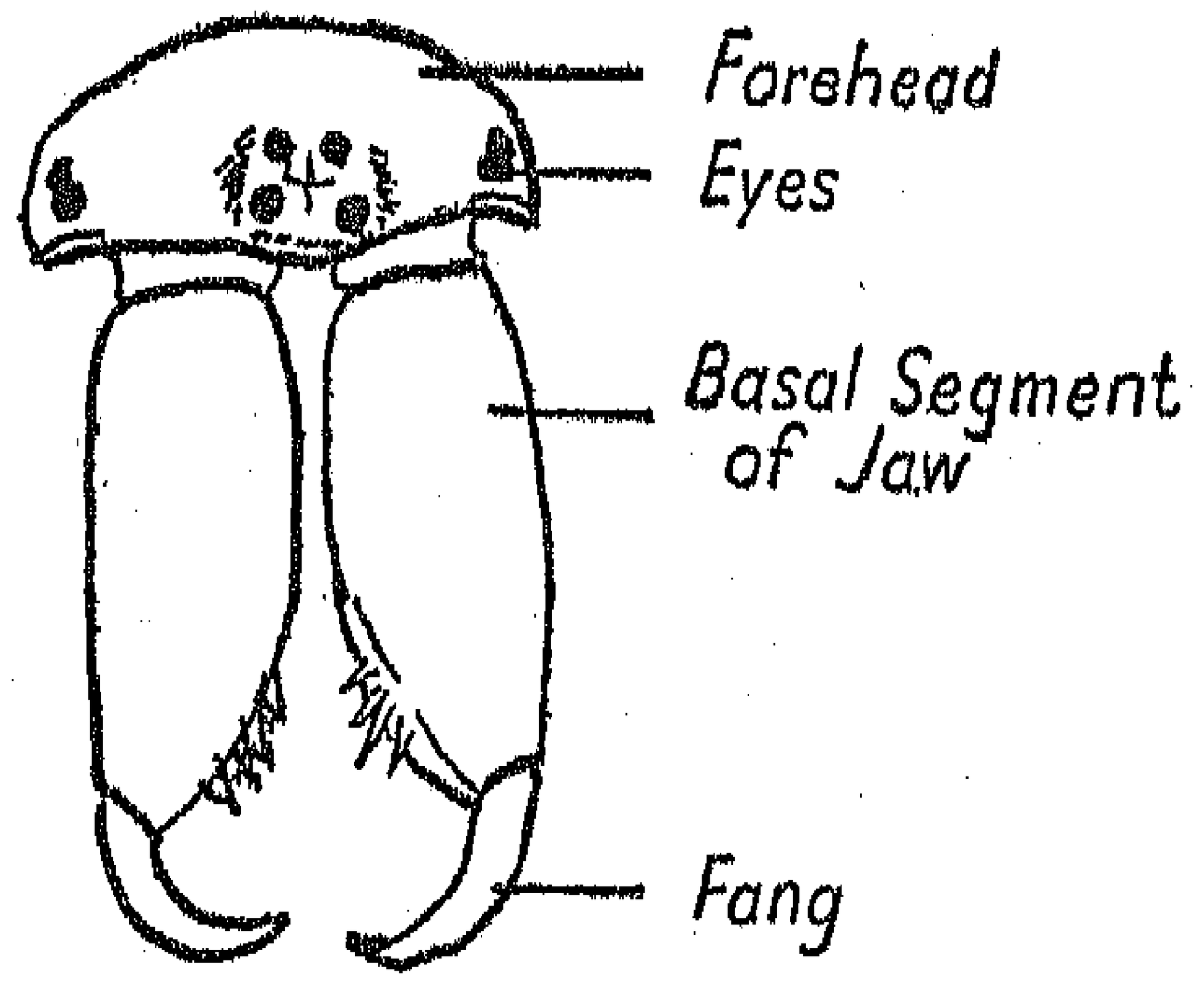


FIG. 105.—Front view of the jaws and forehead of the Garden Spider, considerably enlarged.

If you look at the head of the spider from the front, you will see the jaws. There are two of these, side by side, attached to the head at their top ends, while their other ends hang freely downwards. At the free end each jaw has a curved fang (Fig. 105). If the fangs are not distinctly visible, they can easily be made so with the point of a pin or needle, for if they are pressed downwards in a dead spider they will remain open. If you do open out the fangs, you should be able to see the tiny teeth-like projections on the inner surfaces of the jaws. Use Fig. 105 to help you to identify these structures.

In the head behind the broad part of each jaw is a tiny bag filled with poison. The poison from it travels down a narrow channel which opens on the tip of the fang, so that, when a spider drives its fangs into an insect, the poison is injected into the prey which is rapidly paralysed or killed. No British spider is capable of hurting human beings, though the bites of certain foreign spiders (e.g., the Black Widow) are really dangerous.

The interesting structures on the abdomen are underneath. Near the front end, in mature females, is a small yellowish structure called the *epigyne*, situated in the mid-line. The epigyne is continued backwards as a projection which bears some resemblance to the spout of a kettle. This is the ovipositor, and at its free end is the opening through which the spider's eggs are laid. The epigyne is not present in young female spiders, nor, of course, in males of any age. There is a small black swelling on each side of its base.

Near the ovipositor is a pale area of skin on each side. At the hind end of each is a long thin slit running for a short

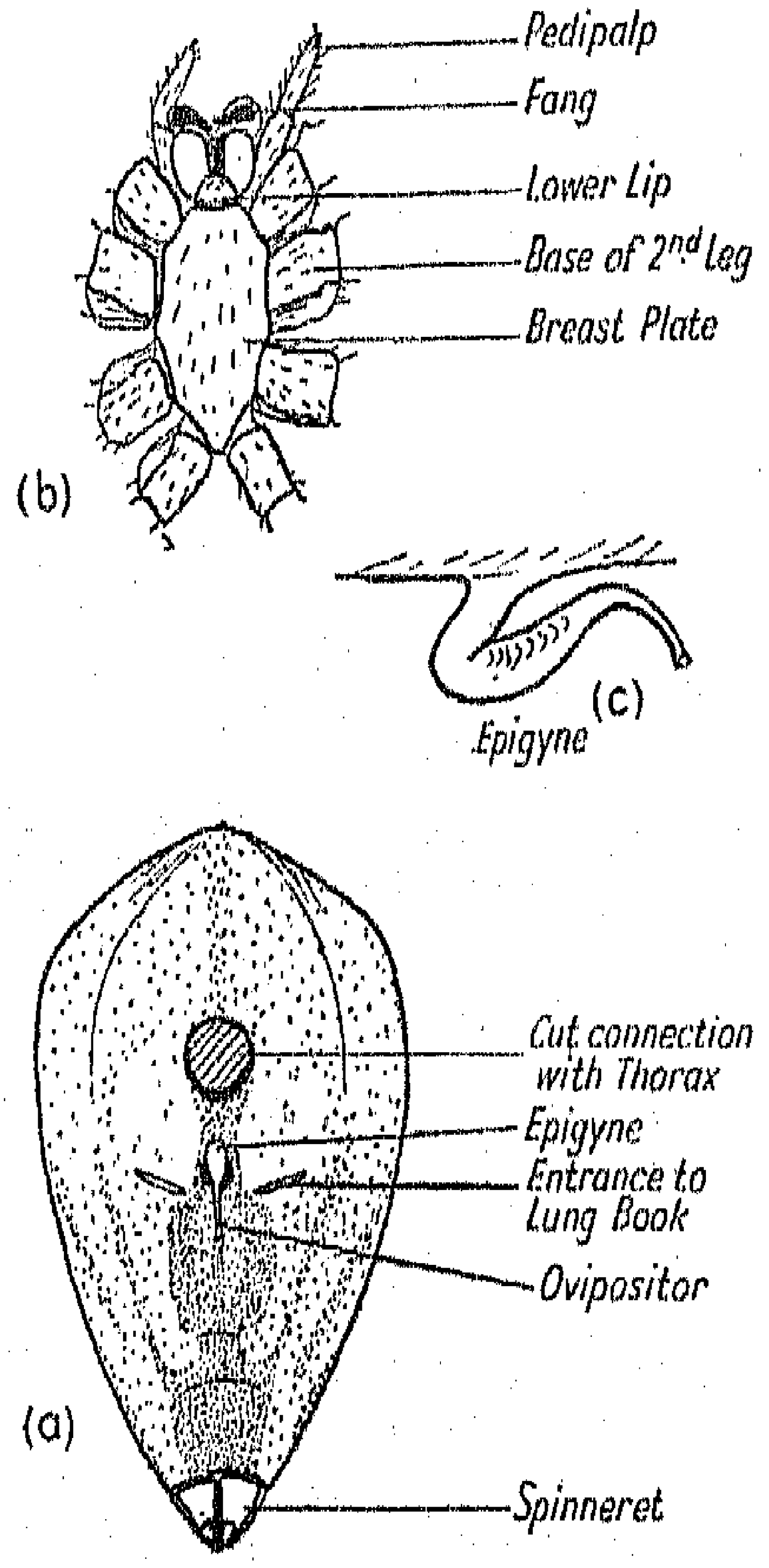


FIG. 106.—Ventral view of: (*a*) the abdomen, and (*b*) the cephalothorax, of the female Garden Spider; (*c*) side view of the epigyne. [(*a*) and (*b*) ×4, (*c*) more highly magnified.]

distance across the spider at right angles to the mid-line of the abdomen. These slits are the entrances to the spider's "lung books", the devices by which the spider obtains oxygen. A lung book really consists of a pouch or chamber pushed in, as it were, from the body surface, and contains a sort of gill.

Near the tail end of the abdomen is a little central projection. When examined with a hand lens this is seen to be made of five parts or flaps. The uppermost part is a little flap on which the anus, the hind end of the food canal, opens. The other four flaps (two pairs) are really conical structures on which the silk glands open, and are called the spinnerets. There is another pair of spinnerets present, but this pair is usually hidden. To get a clearer view of the whole structure, you can squeeze the abdomen gently and the spinnerets should open out from one another. The inner, smaller pair of spinnerets will now be clearly visible. Sometimes, with the help of a brush, it is possible to draw silk from the spinnerets.

The male spiders are smaller than the females and not so easy to discover. As a rule they do not spin webs, but they may sometimes be found near the webs of females during the mating season (September). Males may easily be distinguished because the end segment of each pedipalp is considerably swollen so that it looks rather pear shaped. This swelling contains the male sex cells.

The webs of spiders belonging to the genus *Epeira* are most

elaborate objects. They are made of silk which is given off from the spinnerets. The spider, having chosen a spot likely to be frequented by flies, first constructs a framework of non-sticky threads. Across this framework other non-sticky threads are stretched, crossing in the centre like the spokes of a wheel. Then, starting at the outside, the sticky spiral is made. The spider lays this down carefully, passing from spoke to spoke of the wheel and gradually working inwards. These last threads are at first completely covered with a gummy substance, but, just before she finally fixes them in position, she stretches each thread slightly and then releases it with a little twang. This causes the gummy material to be shaken into tiny droplets so that when observed under a hand lens a sticky thread looks like a string of glistening beads. On some threads the beads may be all the same size, but on others they may be both large and small (Fig. 107).

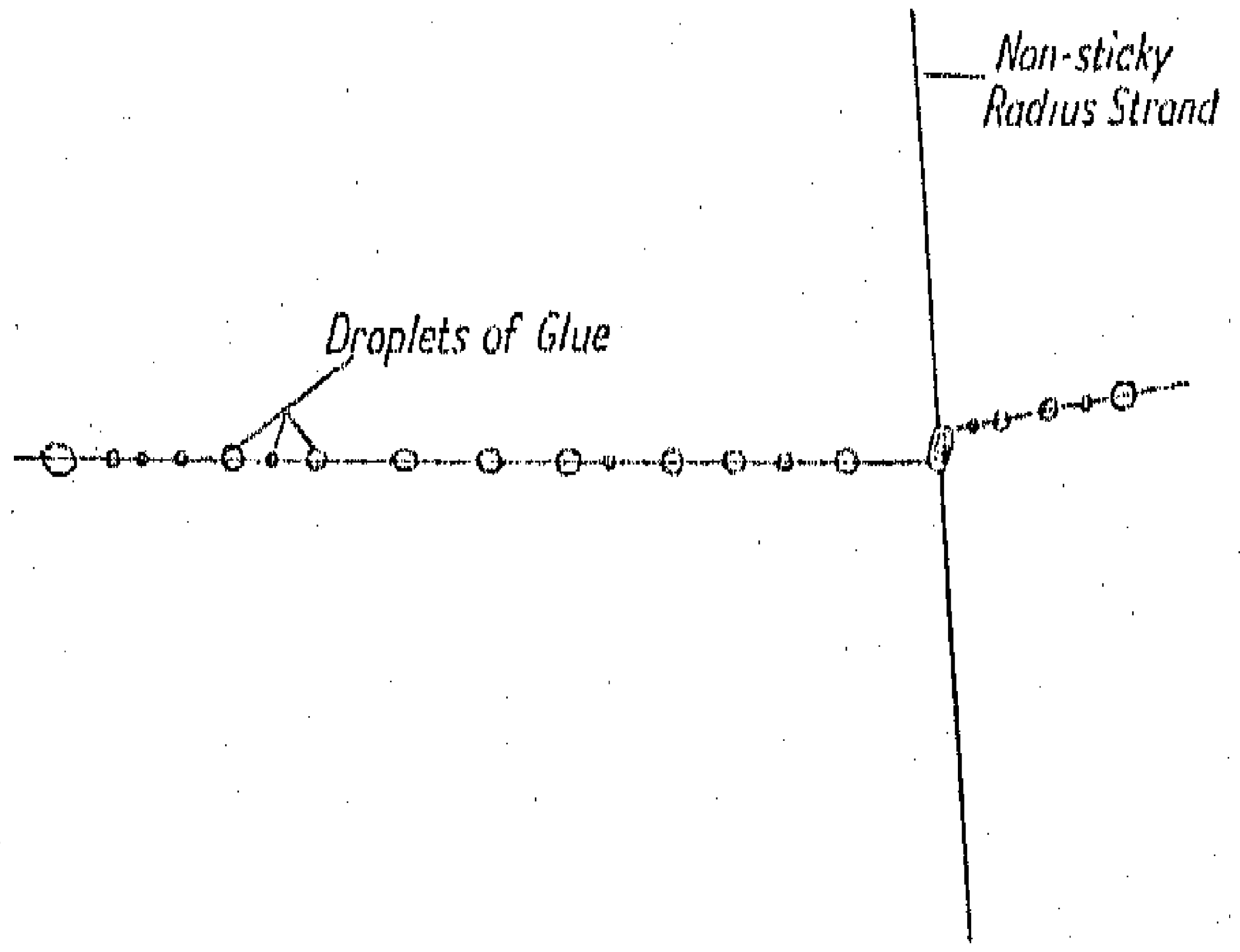


FIG. 107.—Enlarged drawing of a portion of the web of the Garden Spider.

In the very centre of the web, the Garden Spider makes a rather irregular platform of non-sticky threads and frequently she will hang here, head downwards, waiting for insects to fly into the web.

At other times the spider may not be in her web but hidden nearby. In this case there is always a signal thread stretching from the web to the hiding place. The spider lies with one of her legs holding on to this strand. When a fly gets entangled in the web, its struggles set up vibrations which are carried along the signal thread to the hidden spider. At once she rushes out to the centre of the web and then along one of the spokes until she reaches the fly, which is immediately bitten by the poison fangs. When its struggles cease the spider may make a meal by sucking its blood. On the other hand, if she is not hungry, she wraps the insect in silk. To do this, she produces a number of silk threads from the spinnerets and fixes them on to the fly. Then she rapidly twirls the fly over and over with her legs so that in a very short time it is completely swathed in silk. You will often see such flies stored in webs.

Try the experiment of putting flies in spiders' webs, so that you may observe the way the spiders deal with them. Large flies such as blue-bottles are not suitable, as usually they are strong enough to break the strands of the webs and escape.

It is not difficult to obtain a complete small web intact on a piece of clean glass. Choose a suitable web which is easily accessible, and bring the glass up to it, so that the web will be stretched out on the glass. Then with a steady movement press the glass on to the web and continue the movement forwards, so that the supporting strands of the web are broken. The web will stick to the glass. Your first attempts may not be entirely successful—the strands of the web may be displaced—but with a little practice quite good results should be obtained. When you have a suitable web the strands can be made more easily visible by blowing on to the glass a *little* powdered French chalk such as is supplied in cycle repair outfits. If you wish to preserve the web, fix another similar sized sheet of glass over the first, and bind the two sheets together round the edges with sticky brown binding paper.

The eggs of the Garden Spider are laid in Autumn, and are enclosed in a ball of silk thread, light golden yellow in colour, and up to ¾ inch in diameter. This mass of silk is called a cocoon and it is placed in a sheltered spot. Usually the young spiders do not hatch until the next spring. Then they resemble their parents quite closely, except in colour. As they grow they moult several times before they reach maturity.

Among the other British spiders that you are likely to meet are the jumping spiders and the wolf spiders. Neither of these spins webs; instead they both hunt their prey by sight.

One of the Jumping Spiders commonly seen in late summer and early autumn running about on walls, particularly if the sun is out, is the Zebra Spider (Fig. 108). It is quite tiny, but very conspicuous because the abdomen is plainly marked with diagonal black and white stripes, and the rather short legs are also banded with black and white. If you try to pick one up, it will leap away in a most disconcerting manner. These spiders catch their prey by jumping upon it after they have stalked it, or else pounce on it as it approaches the place where they lie in ambush. It is said that, when a Jumping Spider leaps on its prey, it remains attached to its point of take off by a strand of silk which acts as a life line in case of a fall, in much the same way as the ropes used by mountaineers prevent serious accidents. It is not that the spider would hurt itself if it fell, but probably that having once found a good hunting ground on a wall or fence, the spider would take a long while to regain it after tumbling to the ground.

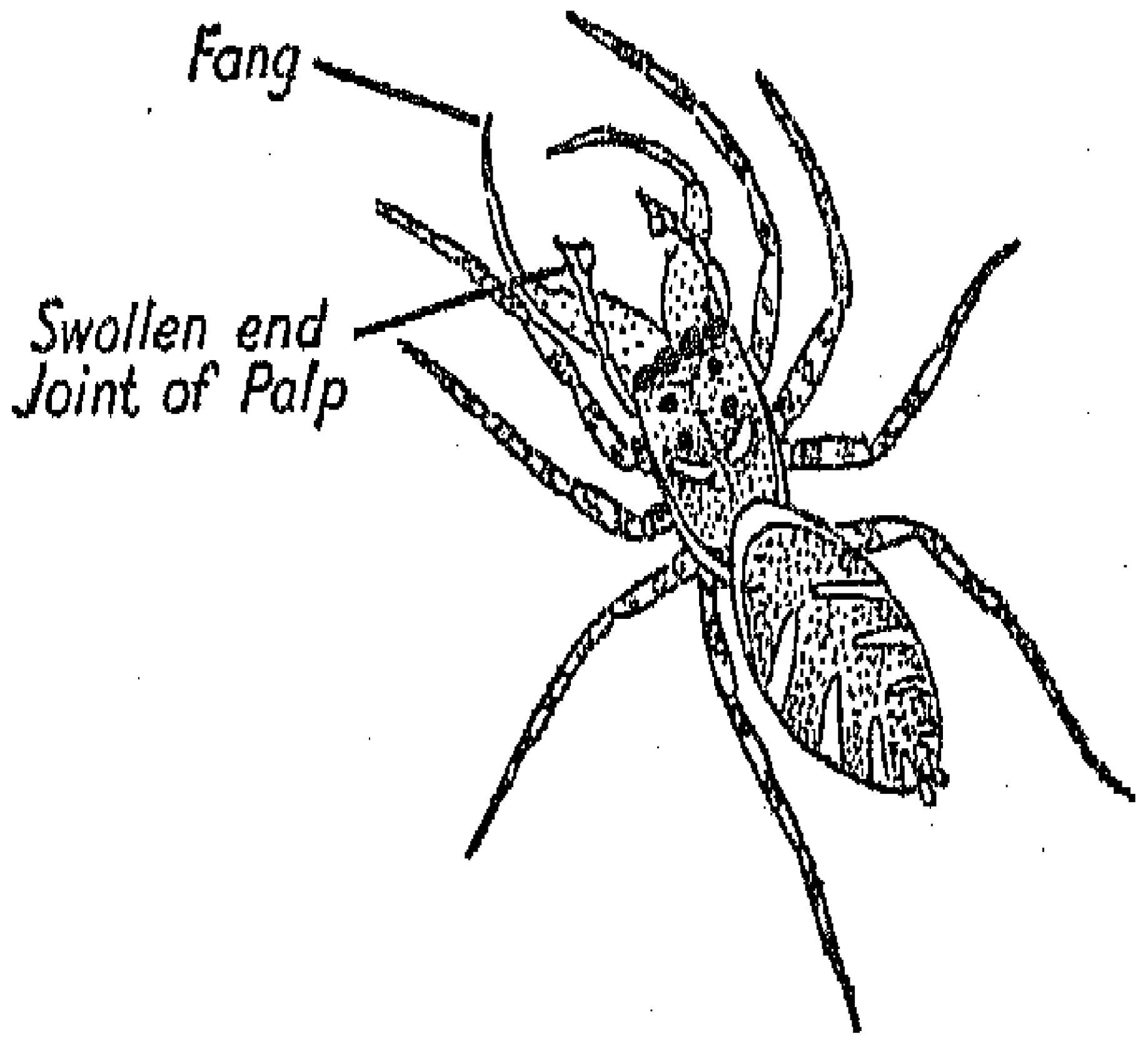

Fang
Swollen end Joint of Palp

Fig. 108.—Male Zebra Spider, ×3.

The Wolf Spiders are slender, dull-coloured animals that look quite fierce as they rove about the ground. If you search in grass or among the herbage in waste ground, you are sure to come across them. They are very quick in their movements and will attack quite large insects. Once when I was out collecting moths at dusk, I had netted a Swallow Tail moth and had laid down the net with the moth in it while I was taking the killing bottle from my bag. Imagine my surprise when, on lifting the net, the moth went sailing away across the grass like a tiny yacht. On looking closer I saw in the dim

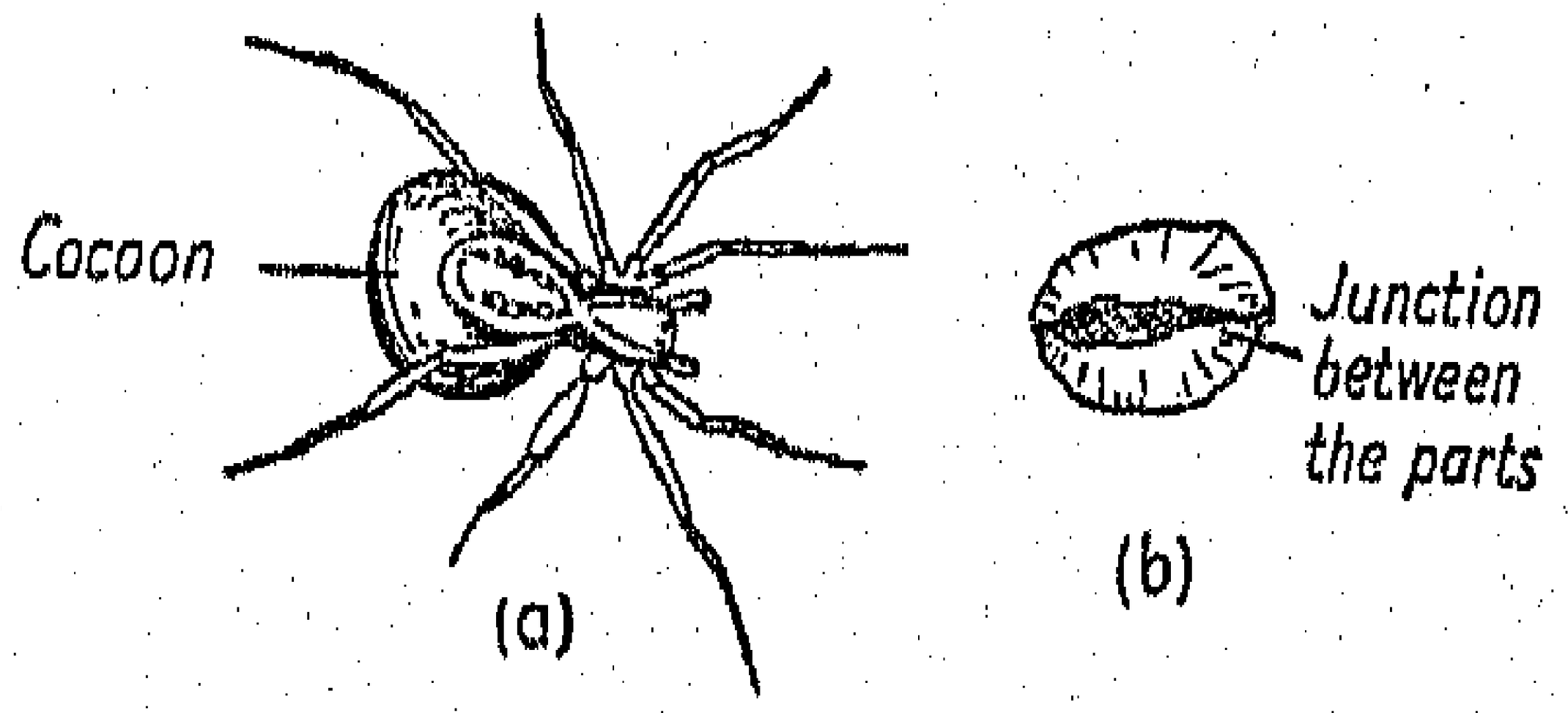


Fig. 109.—(*a*) female Wolf Spider, carrying cocoon, ×2; (*b*) view of the cocoon to show the join between the two halves.

light that it had been seized by a wolf spider which was carrying it away.

The female wolf spiders carry their egg cocoons with them, attached to the underside of the abdomen (Fig. 109). The cocoons are pale straw coloured and more or less spherical. The sphere is made in two halves of stout silk, and round the "equator", where the two halves join, is a belt of thinner silk through which the young make their escape when they are hatched. They do not scatter at once, however, but continue to live in the cocoon for about a fortnight.

The COBWEB SPIDERS include a number of forms whose webs are familiar. The Common House Spider is one of them that builds horizontal webs of fine silk, but the strands are all criss-crossed and not arranged in a neat pattern as they are in the web of the Garden Spider. Although cobwebs cling, the threads are not covered with sticky substance. Seen under a hand lens they are quite smooth.

In autumn, especially after heavy dews, hedgebanks may be seen to be thickly studded with the webs of another cobweb spider *Agelena labyrinthica* (aj-el-eena lab-er-rinth-ika). A rather funnel-shaped mass of cobweb leads into a silk-lined tunnel at the bottom of which lurks the spider which can often be tempted out by twiddling a grass stalk in the web. The spider presumably mistakes the vibrations set up for those caused by the struggles of an insect, and comes out to investigate. Usually it comes no further than the entrance to the tunnel before it discovers its error and retreats.

The COMMON WATER SPIDER is another of these cobweb builders, but in this case the web is woven under water and is used to imprison air. At first the web is horizontal, but as the spider brings down bubbles of air entangled in the hairs of its abdomen (compare p. 265) and releases the air below the web where it is trapped, the web becomes bell-shaped. The Water Spider spins strands of silk from the bell to surrounding weeds, and often travels along these instead of swimming. When it catches food, it retires to the bell to eat it.

Spiders are not a satisfactory group to collect. They cannot well be set on cards like insects because the contents of the abdomen become rotten. However, if you wish to preserve specimens, they can be kept quite well in tubes or small bottles of turpentine or methylated spirits.

A final word of warning may be needed to prevent you from mistaking harvestmen for spiders. It is true that they are somewhat similar, especially in that they have eight legs, but a glance will serve to show you that the narrow waist, which connects the head-thorax with the abdomen in spiders, is absent. The body of a harvestman, in fact, is one piece and the abdomen is connected to the thorax along its entire width (Fig. 110).

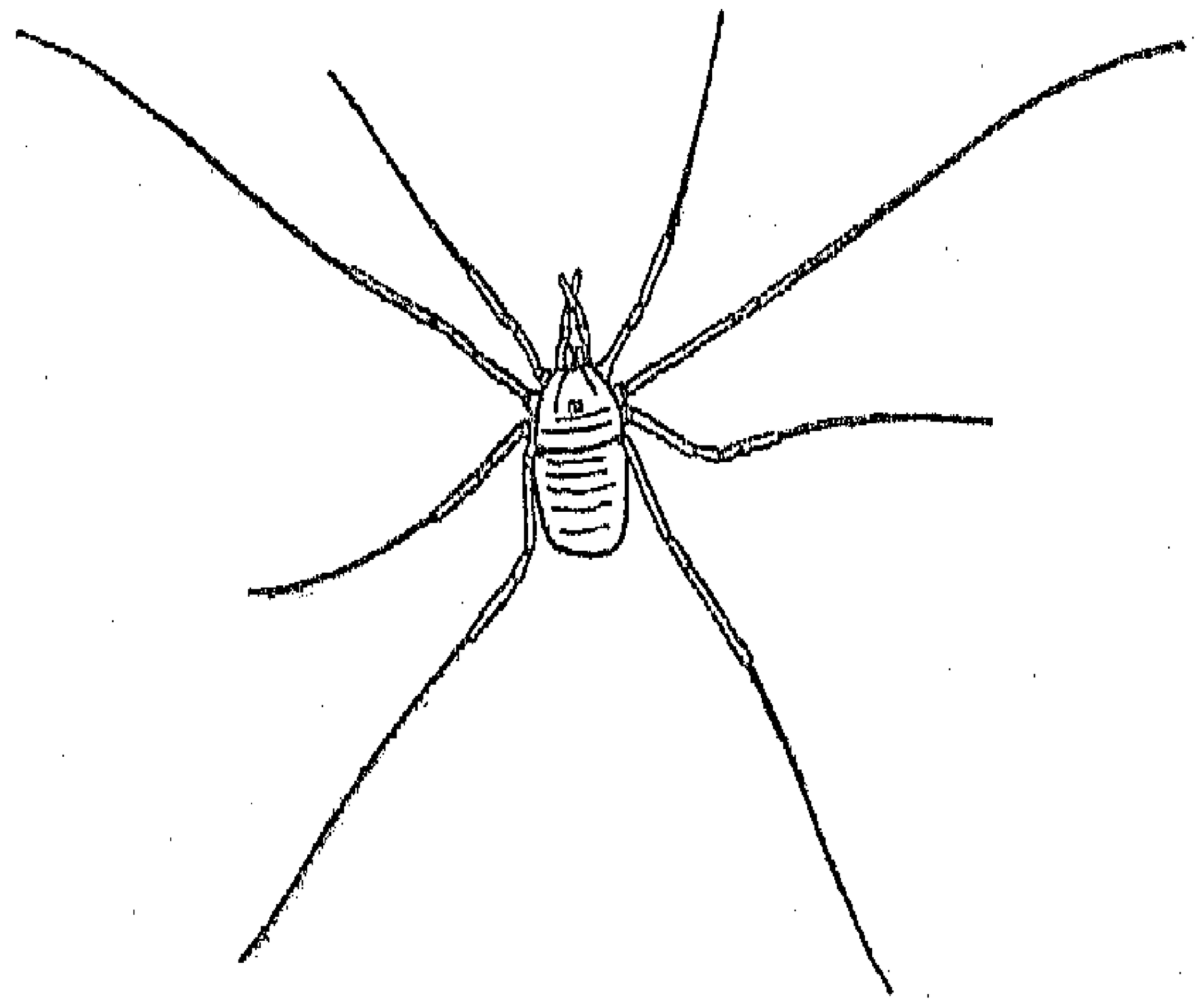


FIG. 110.—Harvestman, × 1½.

The main points of difference between insects, spiders, and harvestmen, are given below:

INSECT	SPIDER	HARVESTMAN
Six legs	Eight legs	Eight legs
Usually wings	No wings	No wings
Body usually divided into three parts	Body divided into two parts	Body not divided

CHAPTER TWENTY

Woodlice

WOODLICE must be familiar to nearly everyone. They are found, often in great numbers, under large stones in rockeries, behind the loose bark of dead tree trunks, under logs on the ground, and in piles of rubbish left lying about the garden. Indeed, they frequent most places where the air is damp and the light does not penetrate.

There are about twenty kinds of British woodlice. The one I shall describe is called the GARDEN SLATER. Its scientific name is *Oniscus asellus* (on-isk-us a-sel-lus).

The Garden Slater is about ½ inch long. When viewed from above, its body has an oval outline with blunt ends and the body is seen to be made up of a number of narrow segments (Fig. 111). It is a steely blue colour with a chain of yellowish spots along each side near the margins, which are also yellowish.

The head is the first of the visible segments. It carries on its undersurface a number of mouth-parts or jaws, but these are too small to be perceived distinctly with a hand lens. In addition there is a pair of eight-joined antennæ, but the segments of the antennæ are not all the same size. The three apical segments are more slender than the rest, and together make up the "lash" or *flagellum* of the antenna (Fig. 111). The remaining segments form the *peduncle*. Near the bases of these antennæ you may be able to see a second pair of tiny antennæ, each consisting of three very small segments. On each side of the head is a conspicuous compound eye which is black in colour and has about twenty prominent rounded facets.

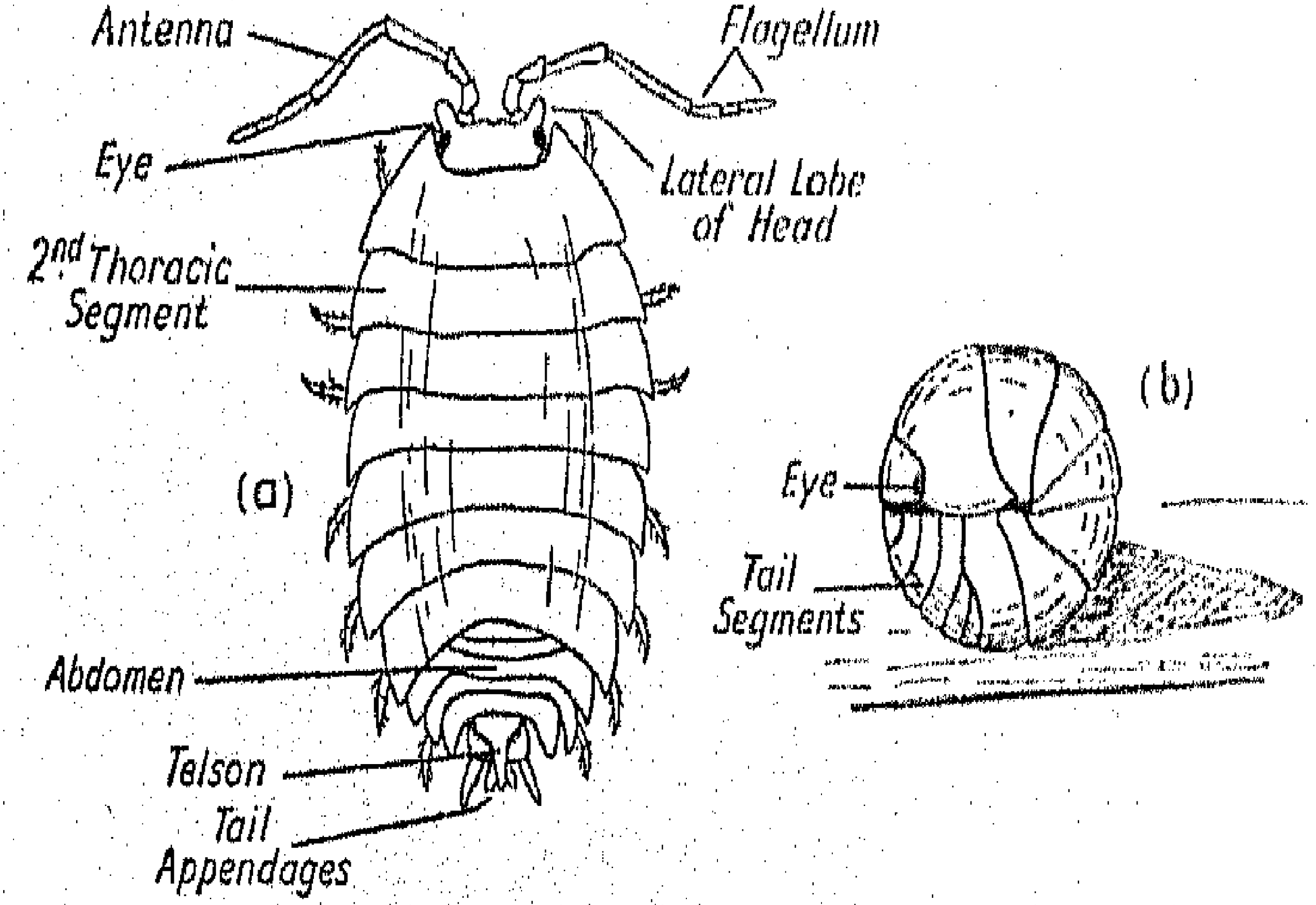


FIG. 111.—(*a*) the Garden Slater, *Oniscus asellus*; (*b*) the Common or Pill Woodlouse, *Armadillidium vulgare*. (Both ×2½).

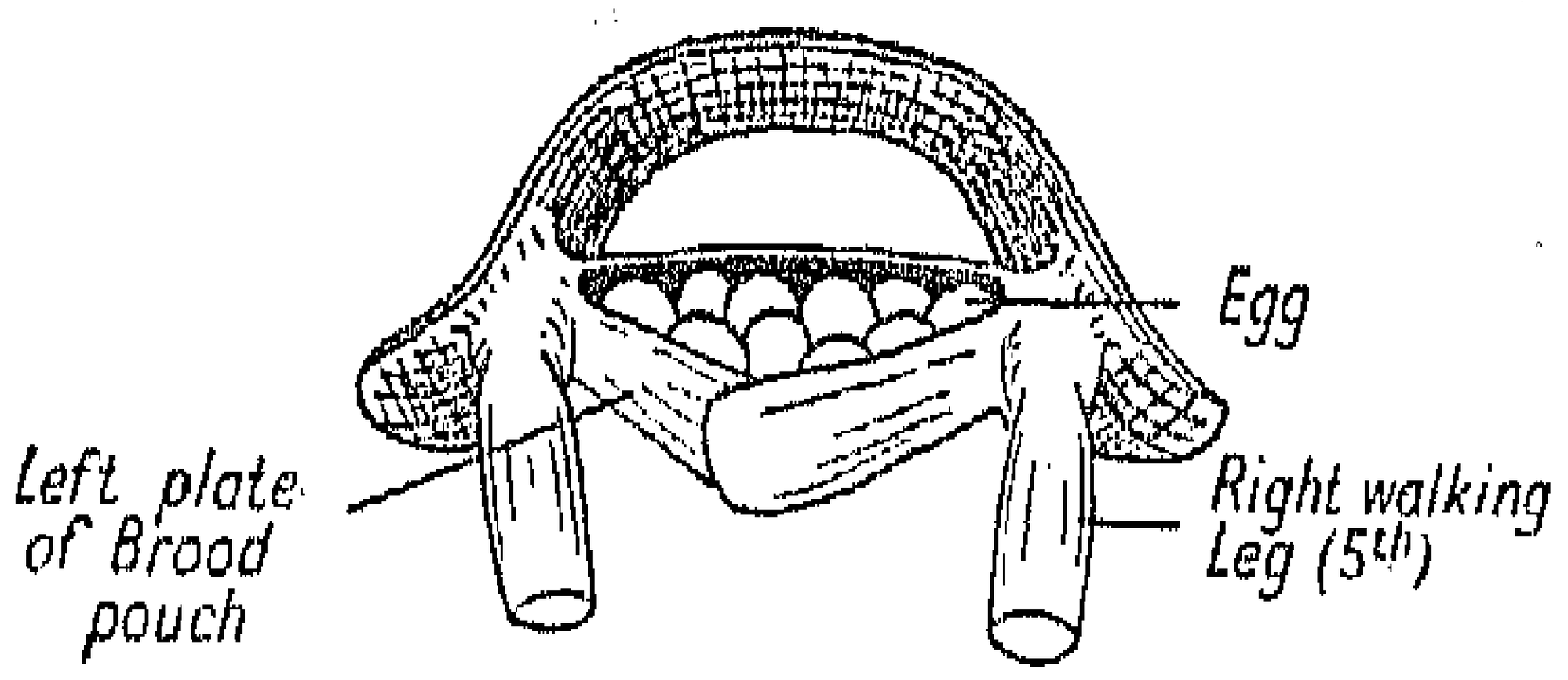


FIG. 112.—Semi-diagrammatic drawing of the fifth thoracic segment of the Garden Slater, to show the brood pouch. (Re-drawn from Sillem and Webb: *The British Woodlice*. Duckworth.)

The seven segments immediately following the head are all alike, and together form the thorax. Each of these segments is drawn out at the sides into thin plates or flanges, and bears two legs on its undersurface (Fig. 112), so that in all there are fourteen of these legs.

The thoracic legs can be seen only by turning the woodlouse on to its back. Each leg consists of five segments, the last two of which are fringed with rather stiff bristles. At the end of each leg is a tiny claw.

The remainder of the body is made up of a further six segments. These together form the abdomen, which is only about one-quarter the length of the whole body. The last abdominal segment bears two pairs of stout processes; the outer process in each pair being the thicker, and consisting of two segments. Between the pairs of processes is a flattish central spine called the telson.

Each abdominal segment, except the last, has a pair of structures on its undersurface. These are flattish plates, and the plates of the various segments overlap one another to a considerable extent. These plates are really much altered legs and they form the breathing organs of the woodlouse. Because they are so very delicate, the breathing organs tend to shrivel very rapidly in dry air, an event that results in the death of the woodlouse. That is why woodlice are found only in moist places.

You may easily make an experiment to find out if woodlice do really need moisture in order to live. Place a few woodlice (e.g., four) in a tin, together with enough dry cotton wool to cover the bottom. Put the same number and the same amount of cotton wool in another tin, but on this occasion damp the cotton wool with water. Fit the lids on the tins and inspect the woodlice at daily intervals. You will soon see whether or not the dampness makes any difference.

Female woodlice lay eggs in early summer. The female keeps the eggs in a special "brood-pouch", which is developed on the underneath of the second, third, fourth and fifth thoracic segments. Plates grow out from the bases of the legs on each side, and overlap in the middle line, making in this way a chamber under the thorax. Fig. 112 should make this clear. The young woodlice remain in the brood pouch for some time after they hatch from the eggs. As the young woodlice grow bigger, they moult several times.

The food of woodlice consists partly of vegetable matter and partly of animal. The woodlice come out into the open at night, and may sometimes be discovered, by means of a torch, feeding on the leaves of young seedlings. Moulting woodlice, whose skin is soft, are said to be eaten by their own kind.

The animal called the COMMON WOODLOUSE (*Armadillidium vulgare*, (ar-ma-dil-id-de-um vul-gare-e), is actually not so common as the Garden Slater (Fig. 111*b*). Its body is narrower, and strongly arched. It is a shining slaty-blue in colour. The paired processes at the tail end are not visible as the animal walks. When touched, members of this species roll into a tight ball so that the top surfaces of the segments are the only structures visible. These creatures are more common in the south of England than in other parts.

Another kind of woodlouse *Platyarthrus hoffmanseggii* (plat-e-ar-thrus hof-man-sej-e-ee), is found living in the nests of certain kinds of ants. This creature has a broad flat body which is white in colour and covered with small wart-like swellings. The lash of the antenna has only one segment, and there are no eyes. The ants pay no attention to the woodlouse. When the ants change their nesting place, the woodlice follow to the new nest.

Woodlice belong to the group of animals we call *Crustaceans*. Other members of this group are lobsters, crabs, shrimps, and prawns, in addition to many freshwater forms. Indeed, most crustaceans live in water, either fresh or salt. If you collect with a net in fresh water, you are certain to come across many of the smaller forms. I will mention three kinds only.

CYCLOPS (Fig. 113*a*). These are quite small creatures, about as big as a small pin-head, which swim actively in short jerks. They can be recognised because the females carry the eggs in two small masses attached to the body, one on each side near to the tail. They are given the name *Cyclops* because they have only one eye which is placed in the centre of the forehead. (Cyclops was a one-eyed giant in the folk-tales of ancient Greece.) *Cyclops* make good food for *Hydra* (see p. 99).

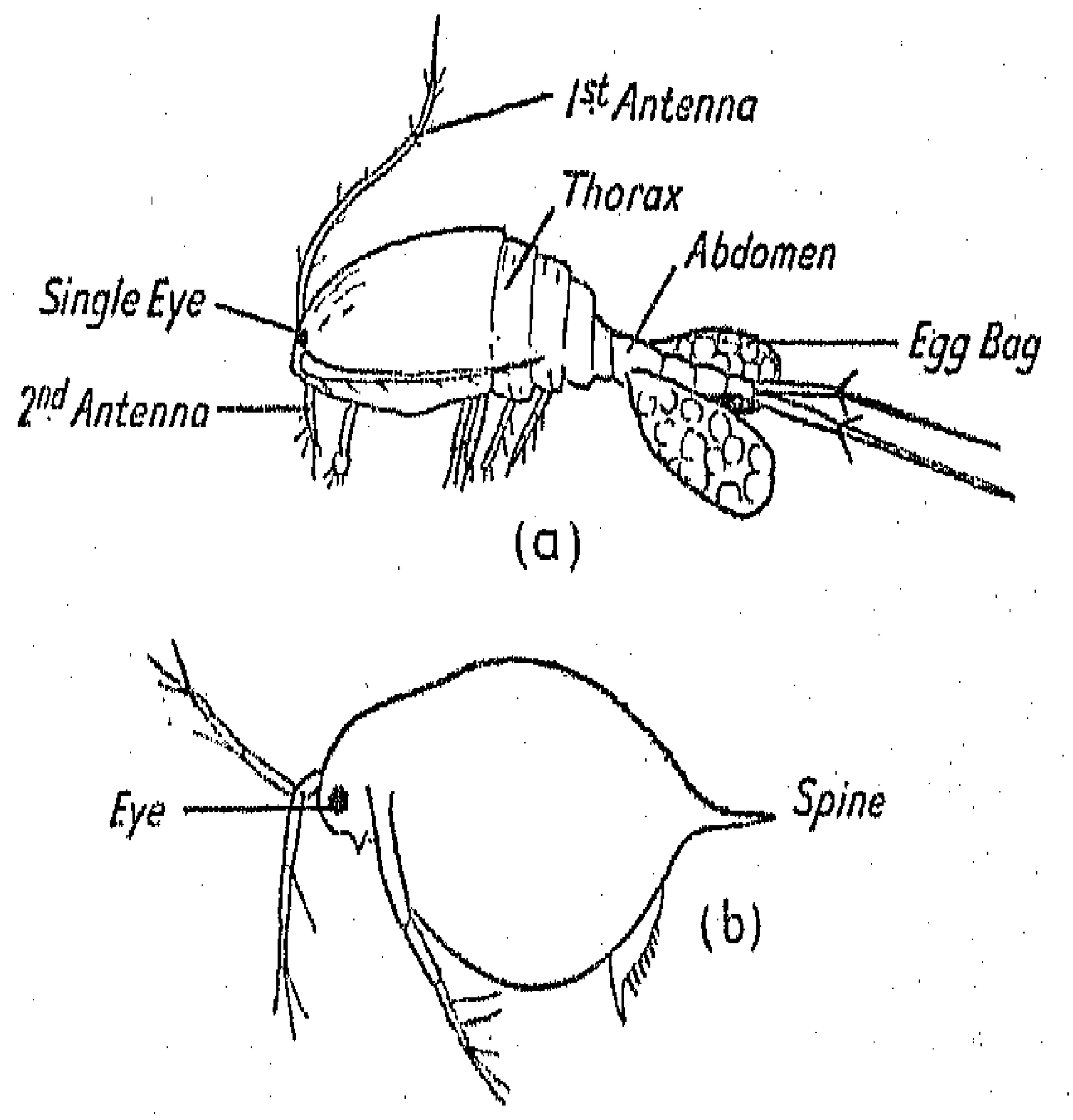


FIG. 113.—(*a*) female *Cyclops*; (*b*) Water Flea (*Daphnia*). (Both ×15.)

WATER FLEAS (Fig. 113*b*). When fully grown these creatures are larger than *Cyclops*. Seen from the side, they are rather square in outline. They swim by vigorous strokes of a pair of large antennæ and move through the water in a jerky manner. They are common in ponds that contain much rotting vegetable matter.

FRESHWATER SHRIMPS (Fig. 114). These creatures are found in running water and several may often be discovered on turning over a large stone in a brook. The males are about ½ inch long, the females smaller. The body is flattened from side to side, and of the general shape shown in Fig. 114. Freshwater shrimps swim about on their sides, either by straightening out

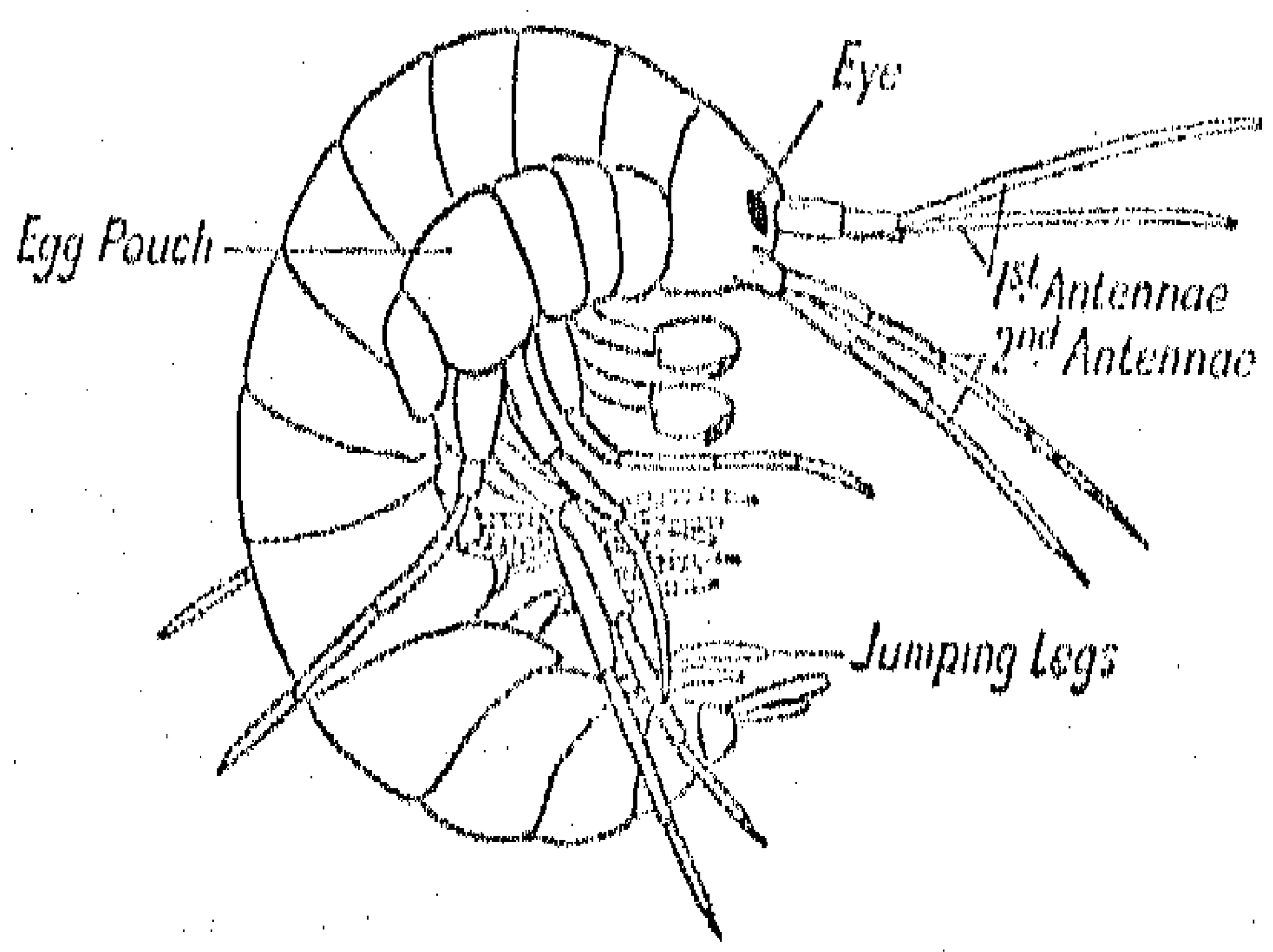


FIG. 114.—Fresh Water Shrimp, *Gammarus*. (×3.)

the curved tail with a flicking movement, or else by paddling with the limbs. During the breeding season the males carry the females around with them, the back of the female lying against the undersurface of the male.

KEY TO THE GENERA OF BRITISH WOODLICE

1	The two divisions of each of the tail appendages alike in shape	8
	The outer divisions of the tail appendages broader than the inner	2
2	Tail appendages projecting when the animal walks	3
	Tail appendages not projecting when animal walks	*Armadillidium*
3	Flagellum of antenna with one segment; eyes missing; habitat, ants' nests	*Platyarthrus*
	Flagellum of antenna with two or more segments; eyes present	4
4	Flagellum of antenna with two segments	6
	Flagellum of antenna with three segments	5
5	Abdomen broad; head with lateral lobes	*Oniscus*
	Abdomen narrow; head without lateral lobes	*Philoscia*
6	Animal able to roll into a complete ball	*Cylisticus*
	Animal not able to roll into complete ball	7
7	Abdomen broad; a projecting lobe on the front of the head	*Porcellio*
	Abdomen narrow; frontal lobe not developed	*Metopornothus*
8	Flagellum with ten or more segments; tail appendages wholly visible; head without lateral lobes	9
	Flagellum with less than ten segments; tail appendages partly covered; head with small lateral lobes	10
9	Abdomen broad; body large; habitat the sea-shore	*Ligia*
	Abdomen narrow; habitat wet moss	*Ligidium*
10	Eyes compound	*Trichoniscus*
	Eyes simple or absent	11
11	Flagellum with four joints	*Trichoniscoides*
	Flagellum with three joints; back with longitudinal ridges	*Haplothalmus*

The genera may be grouped according to the number of segments in the flagellum, as follows:

NUMBER OF SEGMENTS IN FLAGELLUM	GENUS
One	*Platyarthrus*
Two	*Armadillidium* *Porcellio* *Metopornothus*
Three	*Philoscia* *Haplothalmus*
Four	*Trichoniscoides* *Trichoniscus pusillus*
Five-seven	*Trichoniscus vividus* and *T. roseus*
Ten or more	*Ligia* *Ligidium*

SPECIES OF BRITISH WOODLICE

[The following descriptions are taken mainly from *The British Woodlice*, by Sillem and Webb (see p. 328). A few very rare species of British Woodlice are omitted.]

(1) *Ligia oceanica* (lij-e-ah o-se-an-ika). 2 cms. in length. Lives among rocks on the sea-shore.

(2) *Trichoniscus pusillus* (trik-on-isk-us pew-sil-lus). This is a tiny species found commonly amongst the roots of herbage in very moist places. It has a horny translucent appearance and is of a reddish-brown colour. It runs with considerable speed, and when it is moving the white lines with which it is beset are not evident. *T. pusillus* is very like *T. vividus* in colour, but the latter species is nearly twice as big, and has from five to seven segments in the

flagellum, whereas the former never has more than four. The body of *T. pusillus* is smooth and polished. Fairly common.

T. vividus (viv-id-us). Claret-brown in colour; under a hand lens it is seen to be marbled with white. The number of segments in the flagellum varies from five to seven. The body is nearly smooth, with a few scattered, very small, tubercles. Found only in Ireland; rare.

T. roseus (roze-e-us). A deep pink colour, with a yellow stripe down the back. Arranged in transverse rows on the body are large tubercles, each of which will be seen, under a strong magnification, to end in a tiny hair. Found in old gardens; fairly common.

Trichoniscoides sarsi (formerly *Trichoniscus albidus*). It may be distinguished from *T. vividus* and *T. roseus* by the narrow elongated body. The white abdomen is narrow, and the side plates are saw-like along their edges. Very rare.

(3) *Haplothalmus mengii* (haplo-thal-mus men-jo-ee). There is a number of raised longitudinal ribs along each segment of the thorax, the outer ridges being somewhat broken. Two prominent ribs are present on the third segment of the abdomen. Rare.

H. danicus (day-nik-us). Rows of tubercles are present on the thorax instead of ridges, and there are no ribs at all on the abdomen. The front of the head projects further, and forms a more acute point, than in *H. mengii*, and *H. danicus* is not so purely white in colour as the latter species. Rare.

(4) *Oniscus asellus* (on-isk-us a-sel-lus). Slaty grey, with yellowish markings. Young specimens often do not have three distinct segments in the flagellum. Common in moist situations.

(5) *Philoscia muscorum* (fil-osk-ea mus-skor-um). Chiefly found at the roots of grass and under stones and other objects lying on grass. The body is smooth and shining. Characteristic dark markings are present down the middle of the thorax and on the sides, with lighter patches between. Fairly common.

P. couchii (kouch-e-ee). Lead-grey in colour; the antennæ very large and hairy. Inhabits the sea-shore; rare.

(6) *Platyarthrus hoffmanseggii* (plat-e-ar-thrus hoff-man-sej-e-ee). Body white, covered with tubercles. The edges of the side plates are toothed, and the flagellum has but one segment. Eyes are absent. Found in the nests of ants. Very common in some parts.

(7) *Porcellio scaber* (por-sel-le-o skay-ber). Dark grey, sometimes quite red or variegated with yellow. Densely covered with tubercles. The two segments of the flagellum are the same length, and together are equal in length to the last segment of the peduncle. Common.

P. pictus (pik-tus). Head black, with outwardly curved lateral lobes. There is a dark band down the middle of the back, and commonly two others on each side, with more or less conspicuous markings in between. Tubercles are present on the body. The distal segment of the flagellum is only half the length of the proximal one, and the last peduncular segment is longer than the two segments of the flagellum combined. Fairly common.

P. dilatatus (dy-late-ay-tus). More than half as broad as it is long; tuberculated, and a lighter grey than *P. scaber*. The last peduncular segment is longer than the flagellum. Found near houses. Common.

P. rathkei (rath-ke-ee). There is often a light band down the back, and one on either side. The body is smooth. The distal segment of the flagellum is the longer, and the flagellum is equal in length to the last segment of the peduncle. In open fields; fairly common.

P. lævis (lee-vis). The body is light grey with irregular markings; smooth. The large size of this species, and the long tail appendages will help in identifying it. The terminal segment of the flagellum is slightly the longer, and the flagellum is equal in length to the last segment of the peduncle. Usually found amongst vegetable rubbish near houses. Fairly common.

P. ratzeburgii (ratz-bur-je-ee). The frontal lobe is semi-circular, and the lateral plates of the thorax flank the head to a considerable extent. Granulations are present on the middle segments, and the sides of the body are more nearly parallel than in other species of *Porcellio*. The terminal segment of the flagellum is nearly twice as long as the other, and the flagellum is shorter than the last segment of the peduncle. Rather rare.

(8) *Metopornothus pruinosus* (met-o-pawr-no-thus proo-in-ose-us). Undamaged specimens are a beautiful bluish-grey colour, owing to a "bloom" which is easily brushed off, revealing a dark reddish tint beneath it. Antennæ are long and have white markings on them. Fairly common.

M. cingendus (sing-en-dus). Steel blue with red or yellowish spots. It has a raised line across each thoracic segment and its abdomen is narrower than in *M. pruinosus*. Rather rare.

(9) *Cylisticus convexus* (sil-is-tik-us con-veks-us). The side plates of the first thoracic segment entirely flank the head. The sides of the body are straight and the back is arched. Fairly common.

(10) *Armadillidium nasatum* (ar-ma-dil-lid-e-um naze-ayt-um). The body is a delicate brownish-grey, with more or less distinct rows of darker markings. It has a narrow but very prominent frontal lobe, which is almost square and curves somewhat upwards and backwards. The segments of the flagellum are approximately equal,

and together equal in length the last segment of the peduncle. The telson (tail plate) is as long as it is broad at the base, and tapers to a rounded point, while its sides are slightly incurved. The outer divisions of the tail appendages are considerably longer than broad and are more or less paddle shaped. When rolled up, the animal does not make a complete sphere, and the antennæ are not hidden. The body is smooth. Rather rare.

A. vulgare (vul-gare-e). Common or Pill Woodlouse (Fig. 111*b*). The colour varies from slaty-grey to yellowish. The body is smooth, shining, and strongly arched. The frontal lobe is not large, though it is broad, and its margin where it joins the head is rounded and slightly recurved. The terminal segment of the flagellum is somewhat the longer, and the two combined are, as in *A. nasatum*, about the same length as the last segment of the peduncle. The telson has the form of a triangle with the angles cut off. The outer divisions of the tail appendages are considerably broader than long. The animal rolls itself into a perfect sphere. Common.

A. pulchellum (pul-khel-lum). The smallest British species of *Armadillidium*. The colour is a dark brown, and there are four principal series of light patches running down the back, and less well marked variegations in between them. The body is smooth. The frontal lobe projects so as to make the head somewhat triangular. The antennæ are short, and the terminal segment of the flagellum is three times the length of the other, while the two together are not as long as the last peduncular segment. The telson is cut off square at the end so that it is by no means as long as it is broad at the base. Rather rare.

A. depressum (de-press-um). Slaty-grey, with yellowish markings, the body is flatter than in other species, and bears tubercles. The frontal lobe is very prominent and much recurved, and the first thoracic segment appears to have the head completely embedded in it. The two segments of the flagellum are nearly equal in length. The telson is slightly longer than it is broad at the base, and its sides are incurved. Rather rare.

PART III

CHAPTER TWENTY-ONE

Territory and Migration in Bird Life

Territory

DURING the last twenty or thirty years, the study of living birds in their natural surroundings has disclosed a number of interesting facts about bird life and behaviour. One of the most interesting that has been brought to light is the manner in which a number of birds of the same species, living in the same domain, will divide that domain into smaller areas, each of which is owned by one or a pair of birds. In this way the countryside is parcelled out into territories, and the owner of a particular territory will defend it stoutly against trespassing birds of the same species.

The boundaries of a particular territory are usually fairly definite, being marked by such natural objects as hedgerows, streams, or clumps of bushes, though this cannot be so with birds living in the open fields, such as lapwings. The boundaries may change during the year, perhaps because the owner of a neighbouring territory is killed, or because new birds arrive and succeed in establishing themselves.

The size of territories for the smaller singing birds varies from about half an acre up to three acres, but it is not yet possible to lay down a definite rule because our knowledge is insufficient. In some cases birds may occupy the same territory for two or more seasons, but more often a bird possesses a new territory each year.

Some of the best work on territory has been done in connection with ROBINS (Fig. 115). When robins are moulting during July and early August there is no ownership of territory; but in September each male robin, and an occasional female, takes possession of an area of land and defends it as best he can against other robins. The defence is carried out by means of a

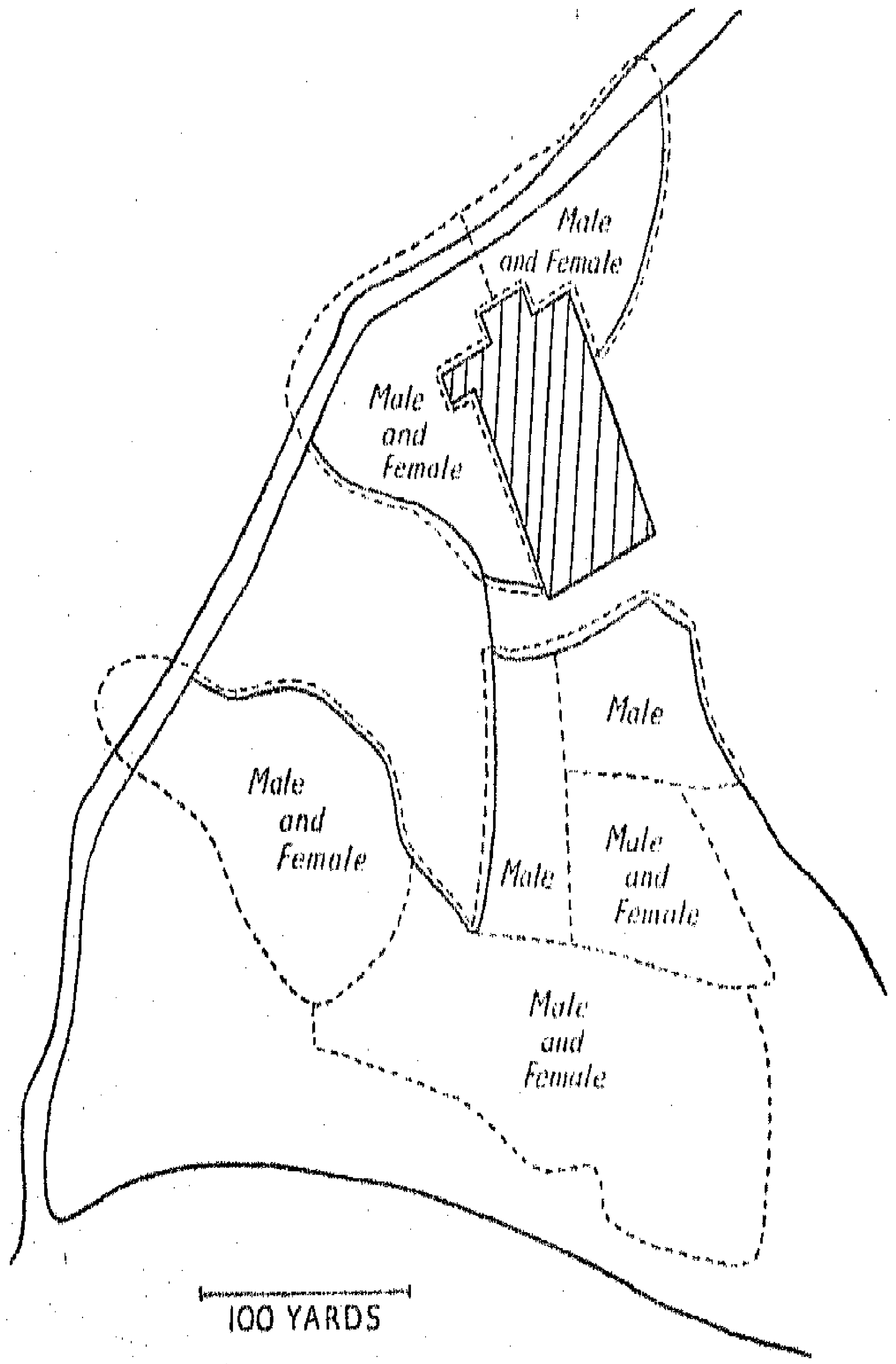


Fig. 115.—Map of robin territories near Dartington Hall, Devon, made by D. Lack, April, 1935. The occupied ground is mostly woodland, orchards, and quarries, whereas the unoccupied areas are mostly open fields. (Redrawn from *The Life of the Robin*. Witherby.)

threatening display, by singing, and by actual fighting. It is a remarkable fact that song is used as a weapon, but such is the case, and this "fighting song" is particularly fine. Many territorial arguments are settled solely by a kind of singing match. The two disputing birds will sing at one another until, finally, one gives in and flies away without any actual fight having taken place. Even when scuffles do occur, the fight may be broken off for short intervals during which both contestants sing loudly. It may be that the song, like the battle cries of warriors, strikes fear into an opponent. Whatever it may be, it is obviously an advantage to the species if disputes can be settled in this harmless manner, because robins have already a sufficiently hard struggle for existence and it would be most undesirable if they were to fight so violently as to wound or kill one another during these frequent territorial wrangles.

It has been shown by experiment that a robin which owns a particular territory will fight and usually vanquish any other robin that trespasses, but, if the first robin happens to stray into the territory of the second, then the tables will be turned and he will fight only half heartedly as if he knew himself to be in the wrong, and will soon be defeated. In other words, when a robin is at home he fights valiantly, but when he is trespassing on another's territory, he resists but feebly and is likely to be driven off easily. This is another reason why these territorial disputes seldom result in death.

As a rule robins do not live more than two or three years —the hazards of existence are too many—so vacant areas are not at first difficult to find. If a male robin without territory is discovered on another's territory he will be furiously attacked, and, as we have seen, in all likelihood driven away. As soon as he passes over the territorial boundary, the attacks of the outraged owner cease. Now if the trespasser returns repeatedly, the attacks on him gradually become weaker and weaker until finally he will succeed in establishing himself on part of the territory. If he can gain pieces of territory in this way from other neighbouring robins, the new-comer will finally be the owner of a suitable area, while the other territories will have become reduced in size.

In December and January, the female robins join the males and form pairs. At this time males in possession of territory sing loudly, especially in the early morning. This behaviour is fairly general among those birds that have the territory habit. In those birds that pass the winter in other countries but come to England to breed, it is usually the males that arrive first and establish themselves in territories. Then they sing loudly, often from favourite "singing-posts" such as the top of a gate or a special branch high up on a tree. Blackbirds and thrushes show very well this use of favoured singing-posts. We must regard this vigorous singing partly as a warning to other male birds of the same species that the territory is occupied and will be defended, and partly as a sign to females in search of a mate that here is a male bird possessing the necessary territory and in need of a mate. After pair-formation, the female soon learns the extent of the territory for, as soon as she strays into neighbouring territories, she will be chased back. In some species of birds the females help in defending the territories against intruders. Usually it is only intruders of the same species of bird that are attacked, while other birds are not molested.

There has been a good deal of discussion as to the actual value of the territorial system in bird life. There can be no doubt that it causes the birds of a particular species to be more or less equally distributed over the available breeding areas. In normal seasons when food is abundant this might not much matter, but in the occasional hard seasons, when food is scarce, it is clearly an advantage. Another point is that it ensures an area around the nest in which other birds of the same kind are not allowed to collect food, so that when the young are nearly full grown and require a large amount of food, a good deal of this may be found near to the nest and so save the parents time in flying to and from the feeding ground. On the other hand, we must not forget that other birds, which may eat the same kind of food (food competitors), may be tolerated in the territory.

I mentioned earlier that it is usually the male robins which take over territory in the autumn, with only a much smaller number of females doing so. You may have wondered what happens to the rest of the females during the winter. Although some of them do stay in the countryside, there is no doubt that others leave England for the winter and come back again in the spring. This brings us to the general problem of bird movements and in particular to those regular mass movements of birds we call migrations.

Bird Movements

It is extremely difficult for any one individual to find out much about bird movement by personal observation, and it is only in the last half century, when many bird lovers and natural history societies in various countries have begun to compare notes, that any real picture of bird movement has been obtained. There are now observation posts scattered all over the world, where people make records of visiting birds. By comparing lists from the various places, it is possible to get a fair idea of the movements of certain kinds of birds. In addition there are now bird-ringing schemes which have as their object the placing of numbered rings on the legs of birds.

The British scheme is run by the British Trust for Ornithology.* The Trust issues special bird rings to its members. The rings are very light and each ring has a number stamped on it.

The people interested in bird-ringing either place the rings on fledgelings, just before they are ready to leave the nest, or else they trap adult birds and place the rings on them. In any case the bird must not be injured. The kind of bird, the place, date, and the number of the ring are written down and finally sent to the headquarters of the Trust. Out of all the birds so ringed some are ultimately found dead or else are trapped again. If the person finding such a bird sends the number of the ring back to the headquarters of the Trust, valuable information about the age and movements of this bird is gained. In these ringing-schemes there are arrangements for various countries to work together.

If you wish to help in the actual ringing you will have to become a member of the Trust—the membership fee is 10s.; but in any case you should always examine any dead bird you find to see if it has a ring on one of its legs. Incidentally, a similar scheme of marking fishes with metal tabs has been operating for some years.

This ringing-work is interesting for those with a love for wild birds, but results are slow to come in and very many rings are never recovered. However, we now have a good deal of information about the movements of birds and it is possible to divide British birds roughly into four classes according to their yearly movements. These classes are:—

(1) Residents
(2) Summer Residents
(3) Winter Residents
(4) Birds of Passage, or Transients

Residents are birds that normally spend the whole of their lives in Britain, though they may move about from place to place to some extent (e.g., the yellow hammer). Other residents are rooks, blue tits, house sparrows and blackbirds (although some blackbirds leave England during the winter). Indeed, it is now becoming clear that many birds which were previously regarded as true residents are not entirely so. While the majority of a species may stay in the British Isles throughout the year, some of its members may leave for the continent at various times. This is true of starlings, wrens, and song-thrushes, as well as of blackbirds. However, the residents form the bulk of the birds one sees in winter and, as explained on p. 298, they may find it difficult to obtain food at this time and many perish of hunger. Cold by itself is not such a serious danger (see p. 299).

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*Its headquarters are at the Bird Room, The British Museum (Natural History), London. S.W.7.

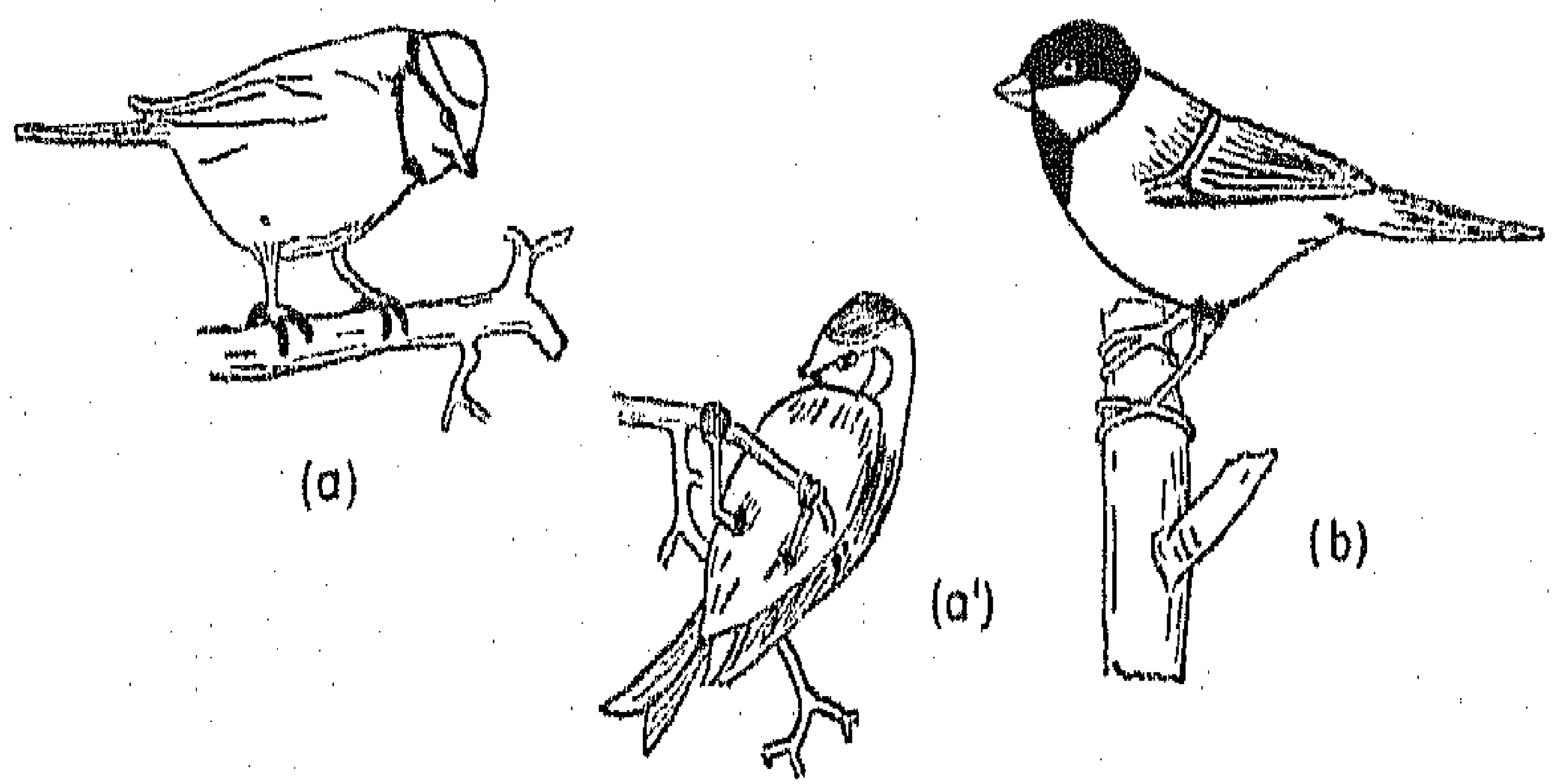

FIG. 116.—(*a*) and (*a'*) Blue Tit; (*b*) Great Tit. Both are resident in Great Britain.

SUMMER RESIDENTS. In this class are all those birds which come to breed in the British Isles during the summer months. They have spent the winter in the warmer countries of the south, especially Africa. During our winter they would be unable to find sufficient food, e.g., swallows live entirely on insects, and insects are very scarce in winter, but in the warmer countries suitable food is abundant. Towards the end of March and the beginning of April they set out towards the British Isles and other northerly countries. When they arrive, they nest and rear their young. Then, in autumn, they depart again before winter sets in. I suppose everyone notices the arrival of the swallows and the cuckoos, as these birds make themselves so obvious, but there is a whole host of summer residents in addition to these: the nightingales, whitethroats, fly-catchers, nightjars, and many others, whose arrival is likely to be noticed only by those specially interested in birds.

Here is a list of a few of our summer residents, together with the places where they spend the winter and the usual time of their arrival in numbers. The actual time of arrival varies from year to year and, of course, is earlier in the south of England than in the north of Scotland, because it takes the birds about a fortnight to make their way through England into Scotland.

The migrant birds of any species do not all arrive on the same day. A few early ones come first, followed a little later by the main body and thereafter by a few late stragglers. In many species the males come first and occupy territories so that all is ready when the females arrive a week or so later.

SUMMER RESIDENT	COUNTRY WHERE WINTER IS PASSED	TIME OF ARRIVAL OF MAIN BODY IN ENGLAND
Yellow Wagtail	N., Tropical, and Equatorial Africa	April 8th
Whitethroat	Tropical, and Equatorial Africa	April 12th
Chiff-chaff	S. Europe, N. Africa and Sudan	March 20th–May 3rd
Nightingale	Tropical Africa	April 13th–May 9th
Spotted Fly-catcher	South Tropical, and Southern Africa	April 28th–May 28th
Swallow	Tropical, Central, and South Africa	March 31st–May 15th
Cuckoo	Equatorial, S. Tropical, and Southern Africa	April 9th–May 22nd
Nightjar	Equatorial, S. Tropical, and S. Africa	April 28th–May 25th

WINTER RESIDENTS are birds that breed much further north than the British Isles, often in the arctic circle where during the summer months there is a plentiful supply of food and long hours of daylight in which to collect it. As you are aware, in summer the days grow longer the nearer one gets to the North

Pole, and at the Pole itself there is continuous daylight for six months. When winter comes on, however, conditions within the arctic circle are very rigorous, so that the birds are forced to move southwards, and many manage to live in the British Isles, especially on the mud flats and salt marshes around the coasts, as these are not likely to be frozen for any length of time. In spring the winter residents move off northwards again to breed. Here are a few winter residents with the countries where they breed in summer.

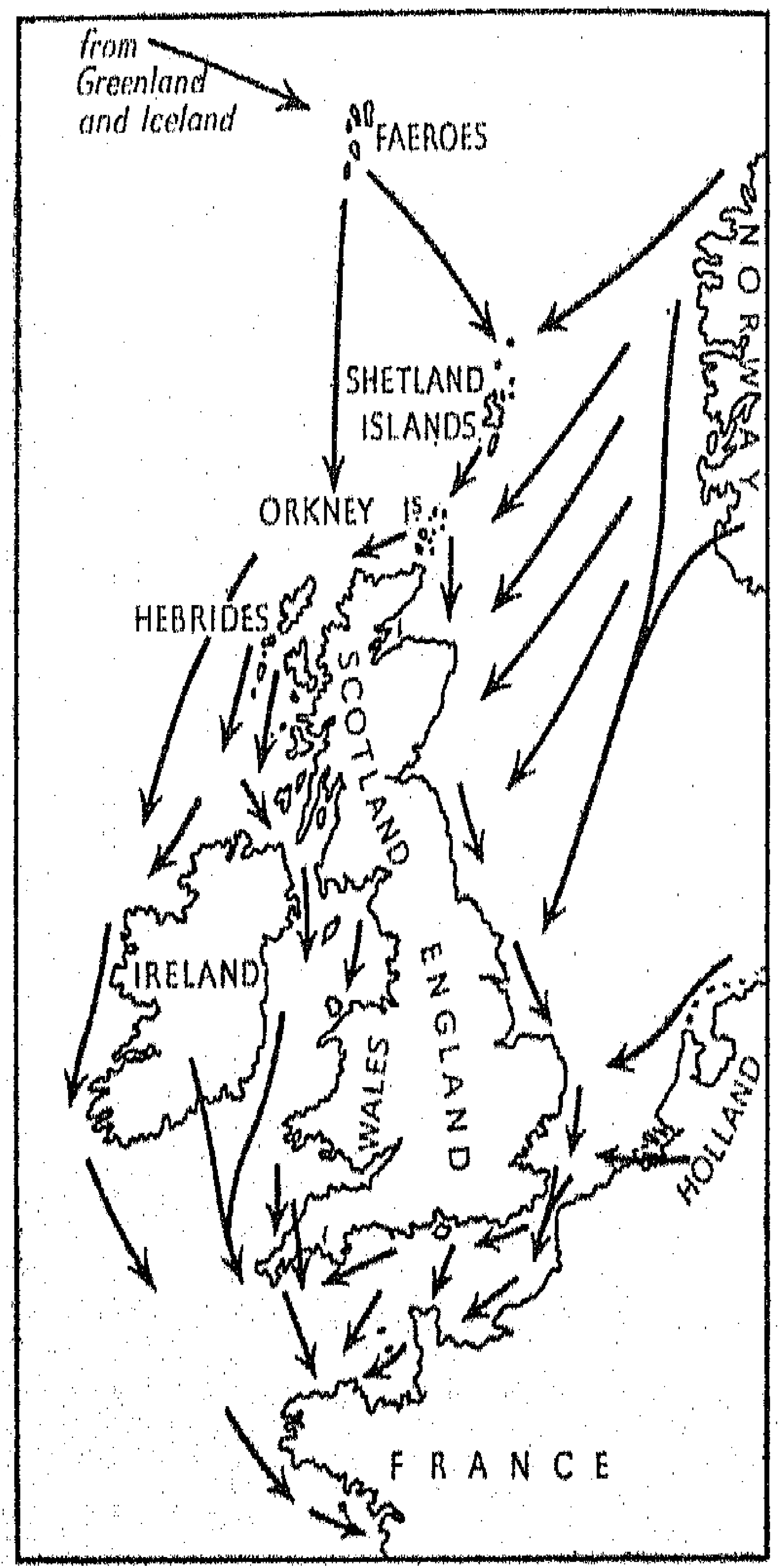

FIG. 117.—Some migratory routes around the British Isles in autumn. (From A. Landsborough Thompson's *Bird Migration*. Witherby,).

WINTER RESIDENT	COUNTRY WHERE SUMMER IS PASSED
Waxwing	N. Finland, N. Russia, Siberia and Arctic America
Brambling	Norway, Lapland, N. Russia
Little Auk	Greenland, Iceland, Spitzbergen
Fieldfare	Northern Europe and Western Siberia
Jack Snipe	N. Scandinavia and Siberia
Snow Bunting	Arctic Europe, America, and Siberia

Birds of Passage are birds that nest in the north and winter in the south. On their migration flights, they pass through the British Isles but stay for only a few days. Arctic terns breed in the arctic but migrate almost from pole to pole to winter in the antarctic. In many bird species, some of the individuals stay the winter with us and so are winter residents, while others pass straight through the British Isles and consequently are birds of passage (e.g., fieldfares).

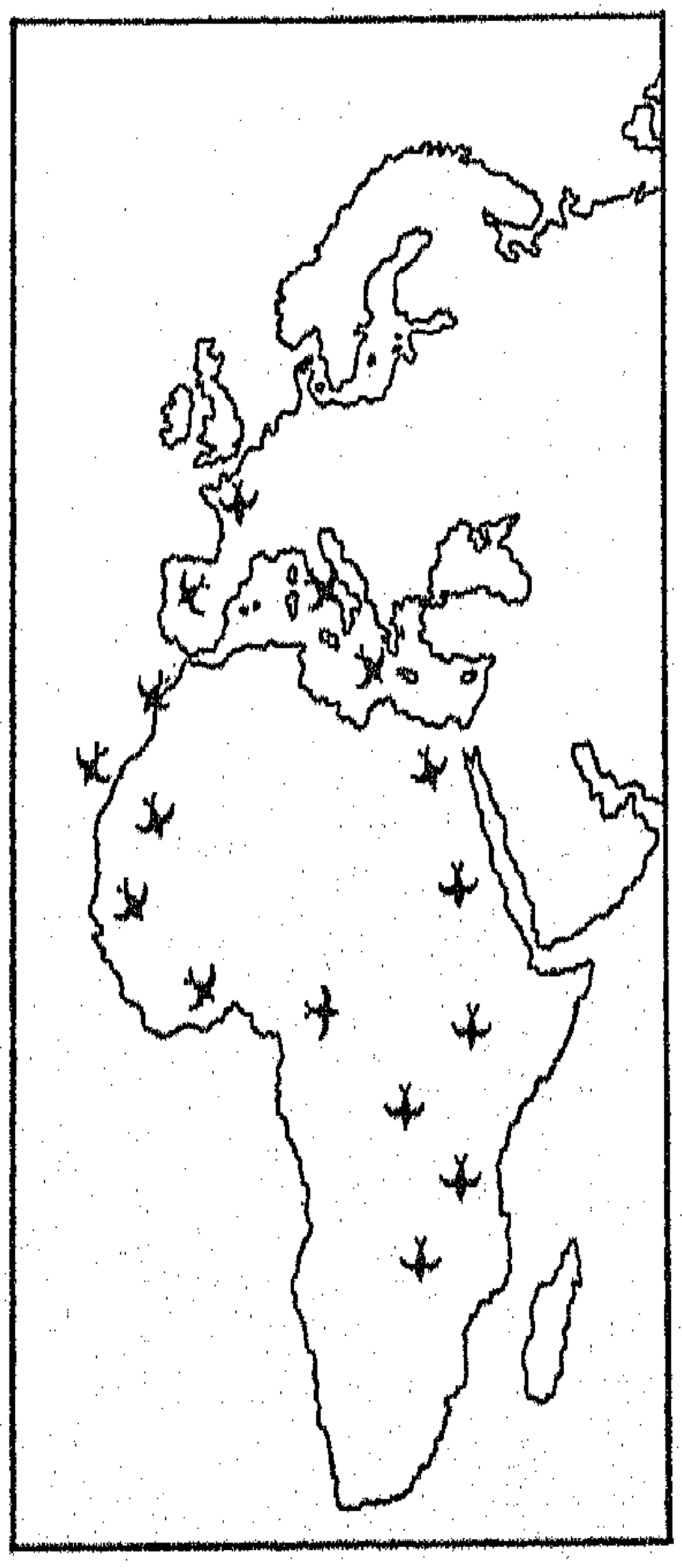

FIG. 118.—Two routes followed by swallows migrating to South Africa. Notice how the birds avoid the great desert area of the Sahara.

This simplified account of migration applies to birds of the British Isles, but is of course not the whole story of bird movements. In the tropics there may be definite migrations in connection with the dry seasons, for drought just as much as cold is unfavourable to life. Even in England there may be considerable movements of birds in response to food supply. For instance, owls and hawks will move to regions where there is a temporary plague of field mice. Again, sewage farms and the mud flats around the coast attract a lot of birds in the winter.

Migration is still somewhat of a mystery. If migrants are imprisoned in cages, they may kill themselves in efforts to escape. How the birds know which direction to take is a complete mystery, and we hide our ignorance by calling it their "instinct". In many cases the old birds leave first, and the young ones follow a few weeks later, so there is no possibility that they are shown the way by their parents. This holds true of cuckoos, since the adults leave in August and the young do not follow until September. It has been suggested that the few extra weeks the youngsters stay are required for them to become strong enough to undertake the long journey.

Migration appears to take place along definite routes, some of which are fairly well known to us (Fig. 117). For instance, Fig. 118, shows two of the migratory routes taken by swallows to reach England from South Africa. Routes for many other birds are along the coasts of the British Isles, and this is one of the reasons that certain islands (e.g., Skokholm off Pembrokeshire) and lighthouses and light ships (e.g., The Kentish Knock) are favourite visiting places for those interested in the study of migration. Local bird watchers know when to expect certain birds to appear at particular places, and records show agreement over a number of years.

You may have wondered by now why it is that you have never seen huge flocks of birds migrating. The answer seems to be that in the British Isles most migratory flight takes place at night, and on clear nights the birds fly high, and mainly along coastal routes. You can, in late summer, observe swallows "flocking up" in great numbers on telephone wires and such like places a few days before they commence their journey southwards. During November, if one listens carefully in inland areas, the calls of migrating redwings may be heard on even the darkest of nights.

Migration is a hazardous undertaking, and many birds are killed or die on the journey. A considerable number of birds lose their way and never reach their destination. We must assume that these are birds in which the "sense of direction" is but poorly developed. There seems to be no doubt that many animals and some of the less civilised races of man do possess such a sense of direction.

CHAPTER TWENTY-TWO

Colour in Animals

WE have seen that colour in the petals of flowers has to perform a task, the task of attracting insects to the flower so that pollen may be carried to the stigmas and so bring about pollination. While it may be going too far to suggest that colour in living things always has some significance for the organism that is coloured, we can usually see that an animal's colour is of some use to it. Often the use is that of advertisement, or concealment, or disguise. In plants, colour is used mainly for advertisement, as in the brightly coloured fruits which it is to the plants' advantage that birds shall see and eat, or in the brightly coloured petals which attract insects.

Anyone who takes an active interest in plants and animals soon comes to realise that in the wild state, more young are created than can grow up into adults. In one year a pair of blue tits may have as many as twenty babies; yet, since the number of blue tits does not increase year by year, it is obvious that most of these young tits will die or be killed before they are themselves able to have young. Or, to take another example, if you go to a meadow and find a buttercup plant, and count the number of carpels in a flower and the number of flowers on a plant, you will realise that all the buttercups in that meadow must together produce an enormous number of seeds. Similarly, in a Warwickshire bluebell wood I estimated that as many as 5,000 bluebell seeds were produced for every square foot of the wood. In spite of this fecundity there will not be appreciably more buttercups or bluebells next year than there are this year. The same is true of frogs, field mice, sticklebacks, and all other living things; the numbers in a particular place remain, in general, fairly constant over a period of years.

It is obvious, then, that all plants and animals must undergo a constant struggle for existence, and that, for various reasons, most of the young fail to live long enough to become adults

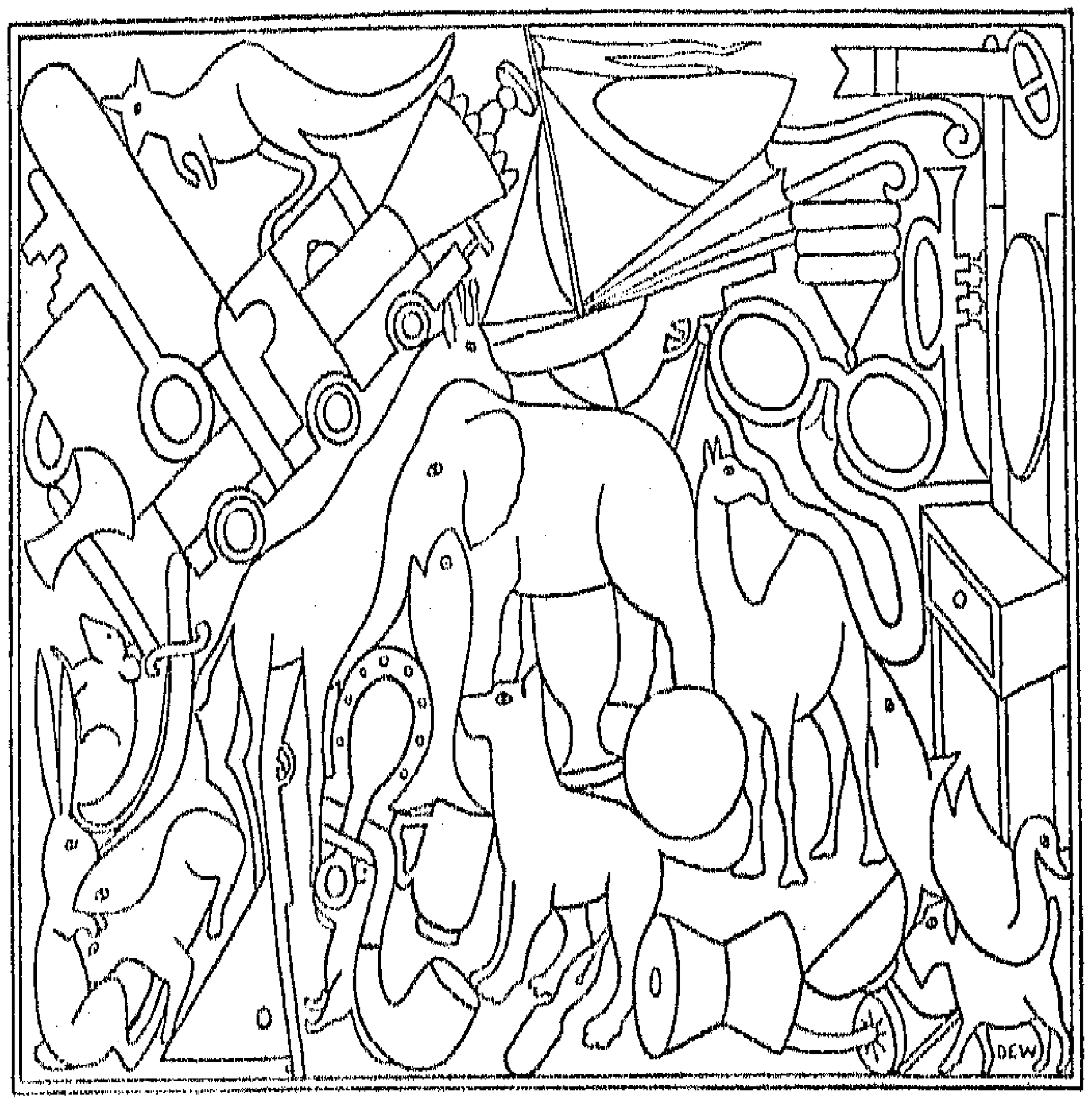

FIG. 119.—Familiar objects may be recognised from their outlines alone. How many can you recognise here? For key to the picture, see p. 304.

and reproduce. In this struggle each species has certain features which tend to help it to survive: examples are offensive weapons such as the stings of wasps or the poison fangs of snakes; the capacity to use a wide range of substances for food as in rats and mice; the ability in plants to ripen seeds in unfavourable conditions, to withstand severe conditions, or to grow in very shaded places.

Colour is used by many, probably most, animals to help in this struggle for existence, and in this chapter I am going to describe to you some of the more obvious ways in which it is employed.

Colouring for Concealment

Colour is often used by animals to conceal themselves so that they may escape the notice of their enemies, or to render themselves less visible so that they will find it easier to catch their prey.

We (and presumably other animals do so as well) recognise objects as solids because of one or more of the following four facts:—

(1) A solid presents to the eye an area of colour. That area of colour may differ from the colour of the surroundings. If it does differ, then it will be visible as a solid.

(2) A solid may be thrown into relief by light and shade on its surface.

(3) Every solid body has an outline which separates that which is the body from that which is not the body. It is this outline which most frequently enables us to detect a body as a *particular kind* of body, i.e., to recognise it by its shape (Fig. 119).

(4) Solid bodies may cast shadows.

Anything that tends to eliminate any of the above points will help to make a body less conspicuous. We shall consider the four points separately:

(1) COLOUR. Many animals have their bodies coloured the exact tint of the background on which they are normally found. You can see this particularly well in certain caterpillars such as that of the Small Cabbage White Butterfly, or the green-flies feeding on rose trees and other plants. Very often the green colour is achieved by the animal itself being transparent so that the green of the food it has eaten can show through. The Privet Hawk Moth caterpillar is green while it is feeding on privet, but, just before it is ready to pupate, it changes its colour to brown. As it pupates in the soil, this colour makes it less conspicuous when it descends from its food plant and travels over the surface of the ground looking for a suitable place.

You will already know that animals which live amid snow and ice are usually white. Even some British animals which in summer are coloured, change to white for the winter; for example, the stoat, which in winter (in the north) becomes the ermine—all white except for the tip of its tail. The ptarmigan is a bird that responds in a similar manner.

The common English frog is capable of changing its colour to some extent. In cold damp surroundings, such as it would experience in the muddy areas around ponds or in ditches, the frog becomes quite dark, but in warm dry surroundings where there is plenty of light, frogs turn a bright brownish yellow, though the body retains the sharp black marks. The frogs one finds away from water in summer are usually of this colour. If you place such a frog in a large tin with a little water and sink the tin in the garden in a *shaded* place, the frog will change to a much darker colour in a day or so.

(2) LIGHT AND SHADE. If the light is coming from above (e.g., the sky) the top parts of solids are more brightly lit and the undersides less brightly lit, because the object itself cuts off some of the light. Hence, in nature, objects that are the same colour all over appear to be lighter on top and darker underneath. This shading device is much used by artists to give the appearance of solidity to their drawings (Fig. 120). If an animal were the same shade all over, it would obviously stand out sharply as a solid, because its top part would be brightly illuminated by light from the sky, while its belly surface would be darker because the animal's own body would cut off some of the light. But if the animal's coat is darker on the back and lighter on the belly, then, when it is illuminated from above, the darker back will look less dark and the lighter belly surface will look more dark, and if the shades are the correct ones the animal may now look the same shade all over. In that case the

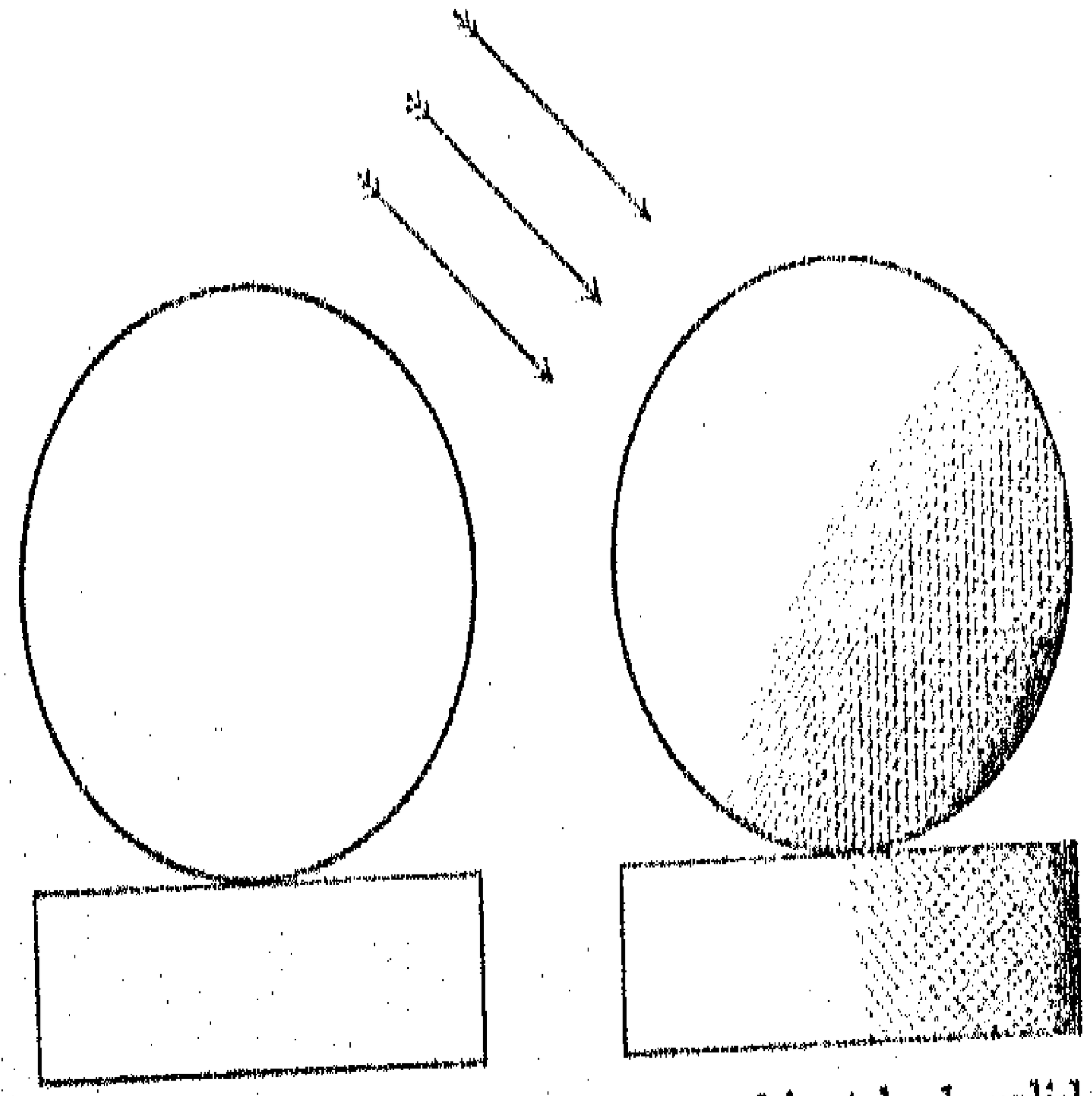

FIG. 120.—In order to make an object look solid, an artist uses light and shade. The parts furthest from the source of light will be darkest, the parts nearest the light source will be brightest.

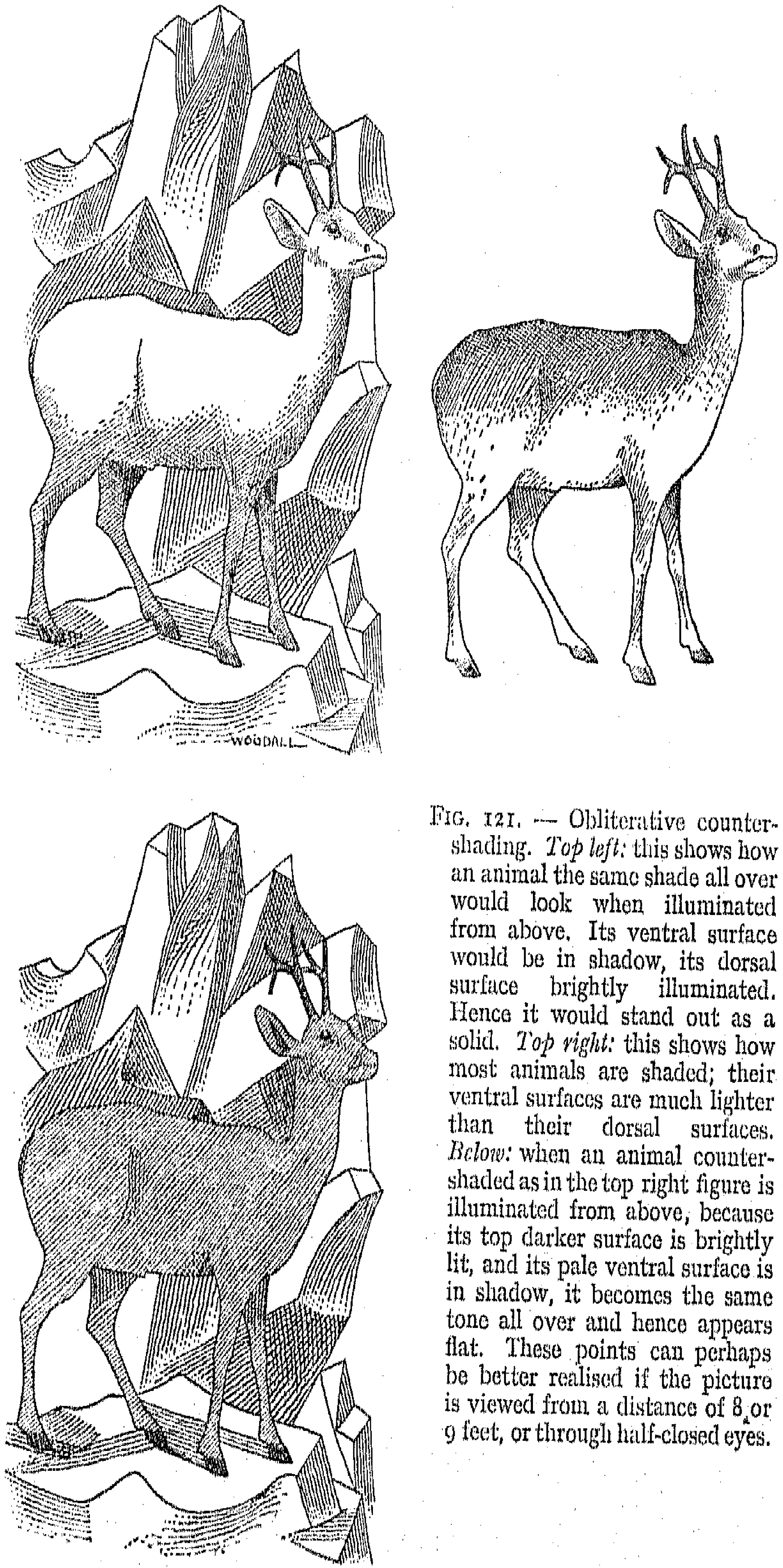

FIG. 121. — Obliterative countershading. *Top left:* this shows how an animal the same shade all over would look when illuminated from above. Its ventral surface would be in shadow, its dorsal surface brightly illuminated. Hence it would stand out as a solid. *Top right:* this shows how most animals are shaded; their ventral surfaces are much lighter than their dorsal surfaces. *Below:* when an animal countershaded as in the top right figure is illuminated from above, because its top darker surface is brightly lit, and its pale ventral surface is in shadow, it becomes the same tone all over and hence appears flat. These points can perhaps be better realised if the picture is viewed from a distance of 8 or 9 feet, or through half-closed eyes.

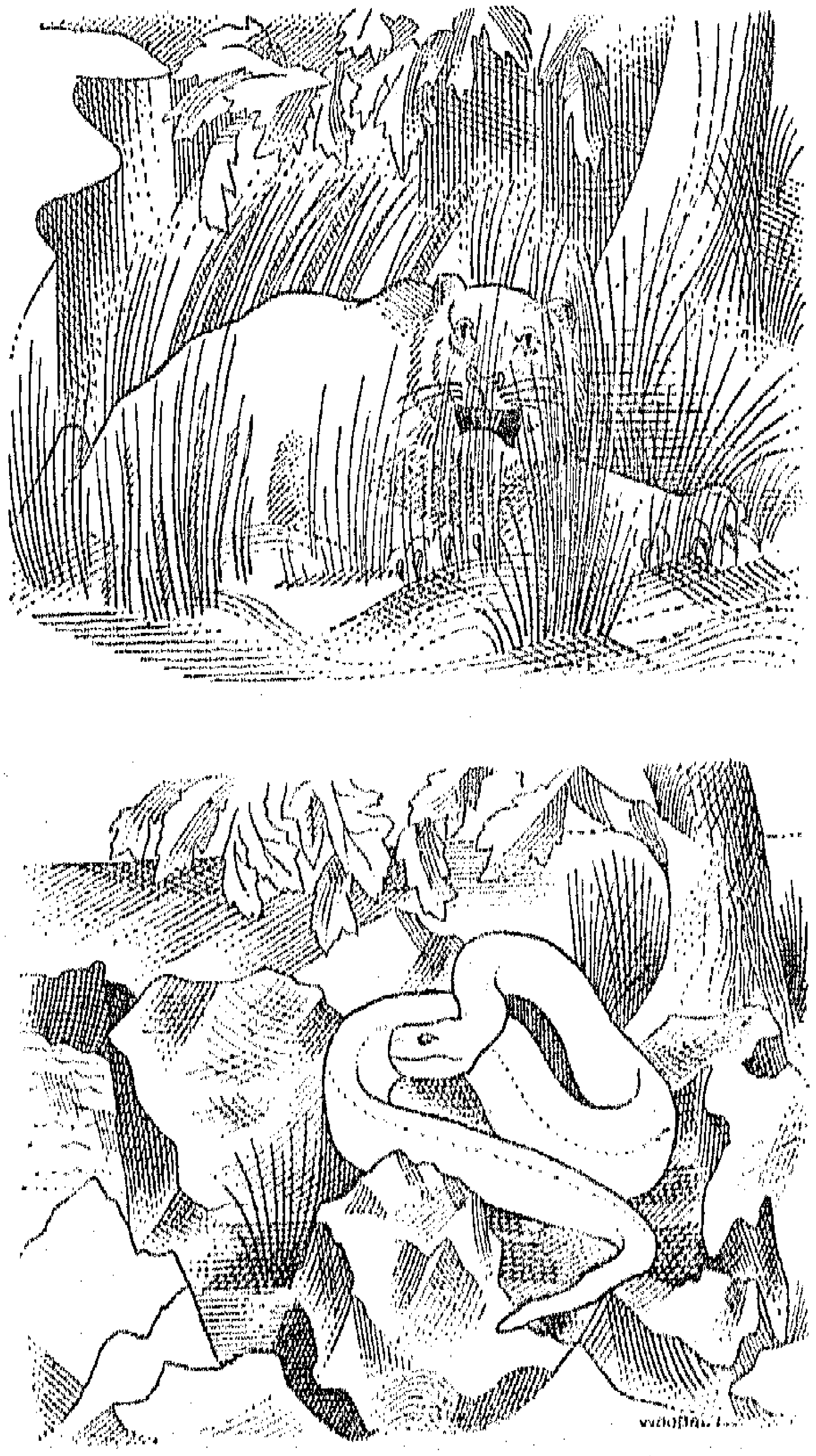

FIG. 122A.—The tiger and snake above are both distinctly visible because they have unbroken outlines (see Fig. 119).

animal would not appear solid, but would seem to be what we call "flat" (Fig. 121). If an object is actually flat, it is difficult to see it among numerous other objects coloured more or less the same. This was brought home to me when training in the Tank Corps—the targets were the shapes of men or guns cut out of flat wood, and they were most difficult to find in the countryside.

Very many animals indeed have the type of shading that makes them appear flat.* They have their backs dark and

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* Obliterative countershading.

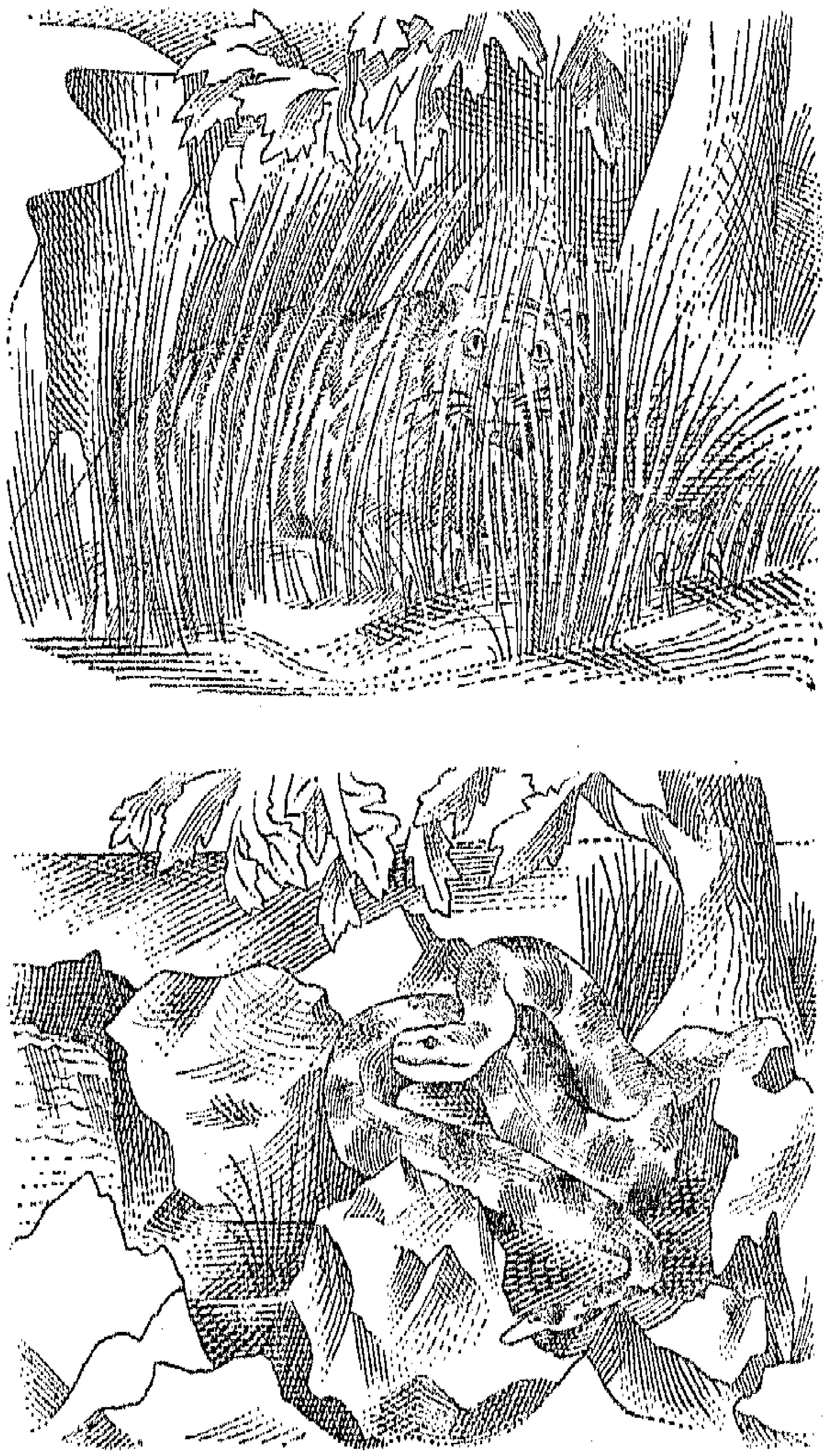

FIG. 122B.—In these drawings the outlines have been broken up by bold blocks of shading, and the animals are now not nearly so obvious. The effect can be more easily appreciated if the picture is viewed from a distance, or through half-closed eyes.

their bellies light in colour. Rabbits show this effect excellently. So do most fishes, as you can easily verify by looking on a fishmonger's slab. When they are lying on their sides, of course, fishes' white bellies show up most prominently, but, when a fish is the right way up in water, it is most difficult to discern from above. In towns you may observe the effect in cats (except those cats that are all black or all white). Many times looking out of my window I have failed to observe a cat on the wall or in the garden until it moved, so well had its colour concealed it. Movement, of course, betrays any scheme of camouflage, because the eye is very sensitive to "flicker".

(3) Outline. Although we see objects as solids because of the effects of light and shade, we recognise them as *particular* objects because of their familiar outlines (Fig. 122A). If the animal is strongly coloured in such a way that its *outline is broken up*, then, at a short distance it may be very easily overlooked, especially when it is in its natural home against a background which is similarly broken up by meaningless blocks of colour (Fig. 122B).

Many moths show this effect very well. Against the plain white of a collector's cabinet they stand out distinctly, but resting on a tree trunk or wall they are much less conspicuous because here the background is broken up with patches of light and shade which merge with the patches of colour on the moths (Plate VI).

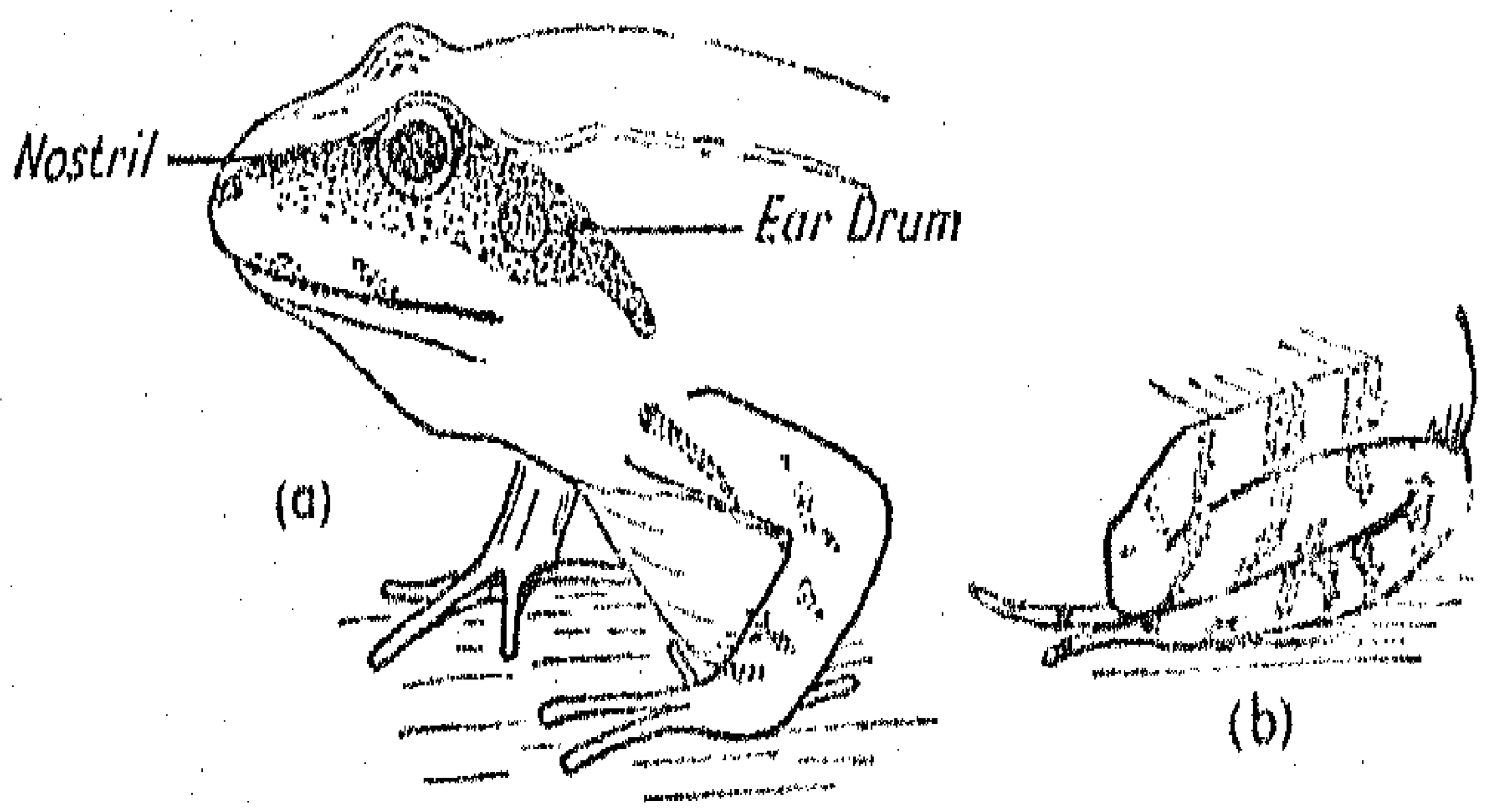

Fig. 123.—(*a*) Head of Common Frog to show how the pupil of the eye is masked by the wedge of dark colour; (*b*) the hind leg of a Common Frog showing how the outlines of the folded segments are concealed by bands of dark pigment which are continuous from one segment to another *across the outlines*.

A good example of how the outline is broken up by patches of colour is provided by the frog. When at rest its hind leg is coloured as shown in Fig. 123*b*. It will be seen that the dark bars on each section of the leg are so arranged that they are continuous across the leg *when it is folded*. This arrangement tends to break up the outline of the frog when it is resting. In the same way the black patch on the frog's head that just includes the pupil of the eye tends to hide the eye (Fig. 123*a*). This is important because the glitter of the eye frequently betrays an animal trying to remain concealed and animals are compelled to keep their eyes open to observe the movements of enemies.

(4) Shadows. Shadows frequently give away the form of solids. I shall not consider them here except to point out that many animals reduce their shadows by crouching close to the ground when they are trying to remain concealed. Butterflies may even turn their bodies at that angle to the sun which casts least shadow.

Warning Coloration

There are some animals with the power to defend themselves if they are attacked, and others that are unpleasant to eat. It is to the advantage of such creatures to be distinctly coloured so that other animals may recognise them easily and thereby avoid them.

We find that this group of animals usually makes no attempt at concealment, and the members are brightly and conspicuously coloured. Black and yellow in combination is a very common scheme, and you will already be familiar with it in wasps and certain of the bumble bees. Both these kinds of insects can inflict painful stings if they are molested. Certain caterpillars, such as that of the Cinnabar moth (Plate VII), and the pupa of the Magpie moth are similarly coloured and are unpalatable to birds, as you can easily verify by offering them to fowls. Old experienced hens will probably have nothing to do with them, but chicks and young hens will very likely peck at them and then spit them out in obvious distaste. (If you make this experiment, remember that even old hens that have lived in towns all their lives may have had no experience of these insects and so may at first accept them.) Wild animals learn very quickly what is dangerous or disagreeable, and, once a bird has tasted a nasty insect, it avoids similarly marked ones in future. Mammals also quickly learn to distinguish unpleasant objects. In 1940 I had a kitten called Dixie that found a bumble bee's nest in the garden. It watched the insects entering and leaving for some time and then tried to catch one with its paws. The bee became annoyed and clung to the kitten under its armpit. Dixie, though apparently not stung—its fur would prevent the bee's sting penetrating—was nevertheless very frightened and rushed indoors with the bee still clinging to it. For a very long time afterwards, it took refuge under a sofa whenever I made a buzzing noise, and even a passing aeroplane caused it to go to the window to investigate. It had learned to associate a particular noise with an unpleasant sensation.

The ordinary white butterflies are very conspicuous, but you will rarely see birds chasing them. The reason again is that these butterflies are distasteful to birds, and the birds presumably learn this fact when they are young. After that they do not waste effort chasing white butterflies, although, as these fly slowly, they would be quite easy to catch. I have only once seen a sparrow pursue a white butterfly, but presumably this was a young sparrow which had yet to learn that white butterflies are not good to eat.

It is not only distinctive colours that are used as a warning. Snakes, and many other animals (e.g., cats), hiss when threatened with attack or injury; and some snakes have a rattle formed of dried bones at the end of the spinal column.

There are some animals which are quite harmless, but are nevertheless dressed in typical warning colours. Many a time I have been out collecting insects with young friends who have mistaken hover flies for wasps, and refused to touch them, although hover flies are quite harmless. During summer, these flies can be seen in gardens, poised in the air motionless (except for their wings), especially over flowers of the Composite family (see p. 23). They have the ability to dart either forwards or backwards.

The imitation of a dangerous species by one that is harmless is called mimicry, and the practice is fairly widespread. The Hornet Clearwing moth mimics a hornet, for example, and quite a number of British beetles look rather like wasps—sufficiently so, at any rate, to make some of my friends hesitate to handle them (Plate VII).

The mimic need not look exactly the same as the dangerous form it imitates. If the resemblance is enough to suggest the dangerous form, wild animals usually prefer not to take the risk, and so the fraud is not discovered.

Many butterflies have very bright attractive areas on their wings. The "eyes" so frequently found (e.g., on the Peacock) are believed to attract the attention of birds so that, when they attack the insect, they peck at the "eyes" instead of at the head

or body of the butterfly. A peck on the wing is not a serious matter for a butterfly for, even if the wing is torn, it can still fly quite well, but a peck on the body would either kill it or seriously disable it. In pecking the wing the bird probably discovers that the butterfly is not good to eat, and so discontinues its attack. It is certain that, if you catch a number of coloured butterflies (particularly old specimens) you will find some with the marks of birds' beaks on their wings, showing that they have been attacked (Plate VI).

Colour in Courtship

An entirely different use of colour in the animal world occurs during the courtship of certain species. Many male moths are attracted to the females by scent; but, at least in some butterflies, there is good evidence that males find the females by sight, presumably recognising the particular pattern of the wings. If you leave the wing of a butterfly such as the Small Tortoiseshell in a garden near plants that are frequented by these insects, you may see Small Tortoiseshells flying above or near the wing suddenly change direction and dip in their flight as if to investigate. This suggests that these insects do recognise one another by the wing pattern. That robins during the breeding season recognise rival robins by the red breast is almost certain, because male robins will fiercely attack dummy birds or even just the red breast of a dead robin mounted on wire, but do not attack stuffed robins whose red feathers have been painted over. Red feathers seem to be a definite signal to robins.

During the breeding season, the ordinary male stickleback develops a vivid red breast and a brilliant blue sheen around the eyes and front part of the body, and we believe that this bright colour influences female sticklebacks to lay their eggs in the nest constructed by the male. Similarly the bright colours developed by male newts during the breeding season, the development of brightly coloured patches of skin in certain monkeys, and the display of brightly coloured feathers by many birds at these times, are considered by naturalists to help in inducing successful mating.

CHAPTER TWENTY-THREE

Seeds and Seedlings

IN Chapter 3 (p. 20) I explained what is meant by the word "fruit"; but in order that you may be quite clear concerning the difference between a fruit and a seed it is necessary to enter here into a little more detail concerning them.

We saw that the pistil (or female parts) of a flower is made up of one, or sometimes several, carpels. When the carpels are separate from one another, each consists of an ovary, style, and stigma; and when the carpels are joined together, these three parts can be distinguished in the whole pistil (e.g., tulip). The ovary contains one or more ovules. After a pollen grain has been received on the stigma it sends out a living tube which grows down the style until it reaches the ovule. A male element, corresponding to a sperm in animals, now passes from the pollen tube into the ovule to fertilise it.

As soon as an ovule is fertilised, it begins to develop into a seed. At the same time the ovary walls begin to develop, growing larger and often becoming fleshy (e.g., in gooseberry, or tomato), but in other instances finally becoming dry (e.g., tulip, or wallflower). The ripe ovary—whether fleshy or dry—is called a fruit, and inside it are the seeds (ripe ovules).

Because the fruit is a ripe ovary, we should expect to find traces of the style on it, at the end away from where it is fixed to the stem. Such traces are always present, and in those fruits developed from inferior ovaries (e.g., daffodil, apple) there are the remains or scars of other parts (sepals and petals) as well. The remains are clearly visible in bananas, currants, gooseberries, and apples.

Sometimes other structures besides the ovary wall help in forming the fruit, e.g., in apples, strawberries, and rose hips, where the fleshy part is the swollen tip of the stem on which the pistil rests. In a dandelion fruit the fluffy parachute is made from the sepals. Before the fruit develops, these are quite small, but after fertilisation they grow rapidly to form the pappus that enables the fruit to be blown about by the wind.

Where the pistil consists of several separate carpels, these may remain together in the ripe fruits, each of which then consists of a number of fruitlets. This is so in blackberries and raspberries. If you examine one of these fruits, the individual fruitlets will be easily seen (Fig. 124).

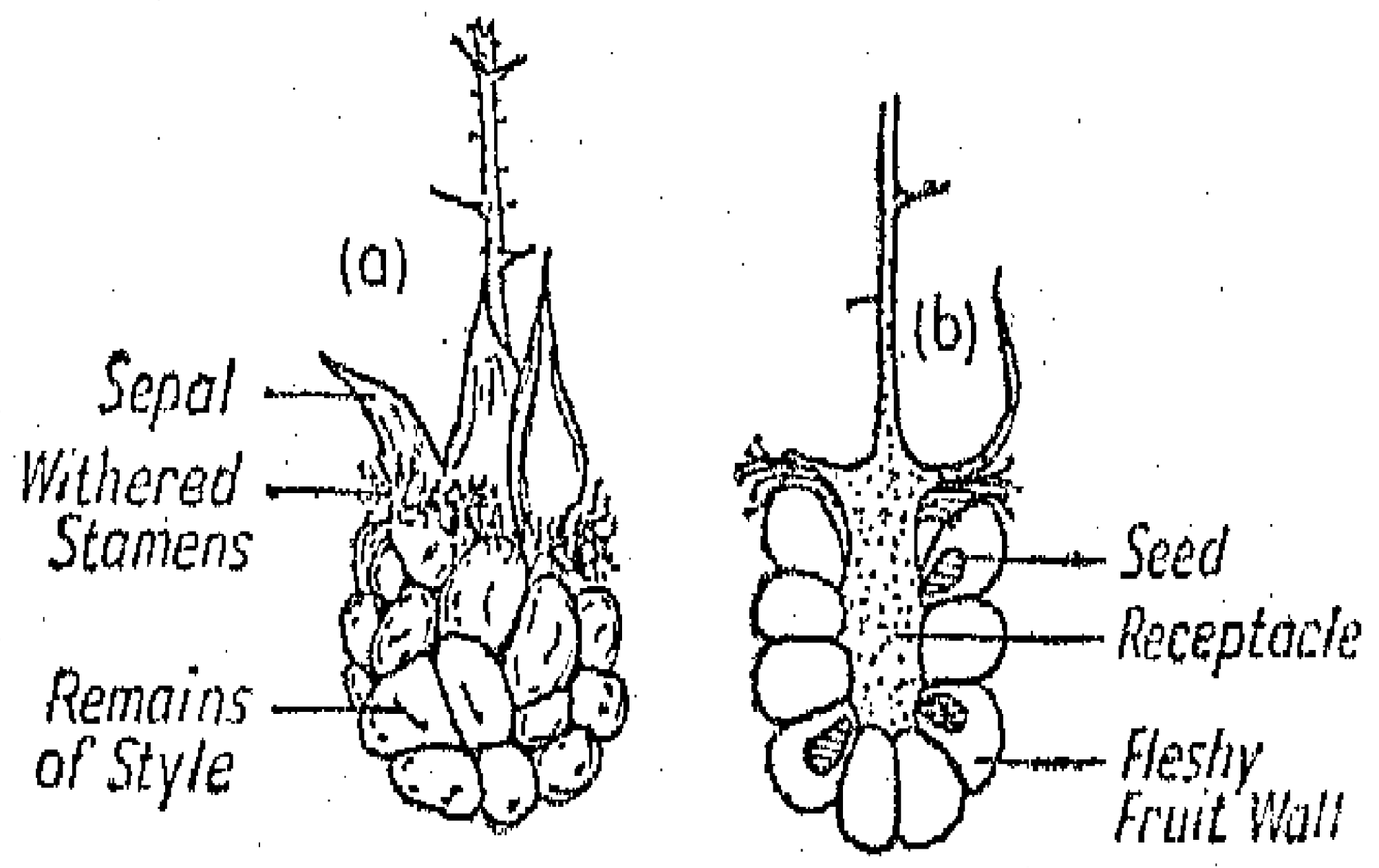

FIG. 124.—(*a*) a ripe blackberry fruit; (*b*) the same in longitudinal section. (×1.)

From what I have already said, it should be clear that the seeds are inside the fruit, and are the result of the development of the fertilised ovules. Each ovule is connected to the ovary by a single stalk, and, when the seeds are ripe, they drop off from their seed stalks. At the point where a seed was connected to the seed stalk, a scar is left. This scar, the hilum, is always present on a seed and is the *only* scar present. A fruit, we have seen, has two scars, one the remains of the style, the other where the fruit was connected to the flower stalk. When a fruit contains more than one seed there is no difficulty in recognising it as a fruit. However, certain dry fruit contain a single seed, and they are apt to be mistaken for seeds, but, if you use the information I have given you, it should not be difficult to determine the nature of any particular specimen.

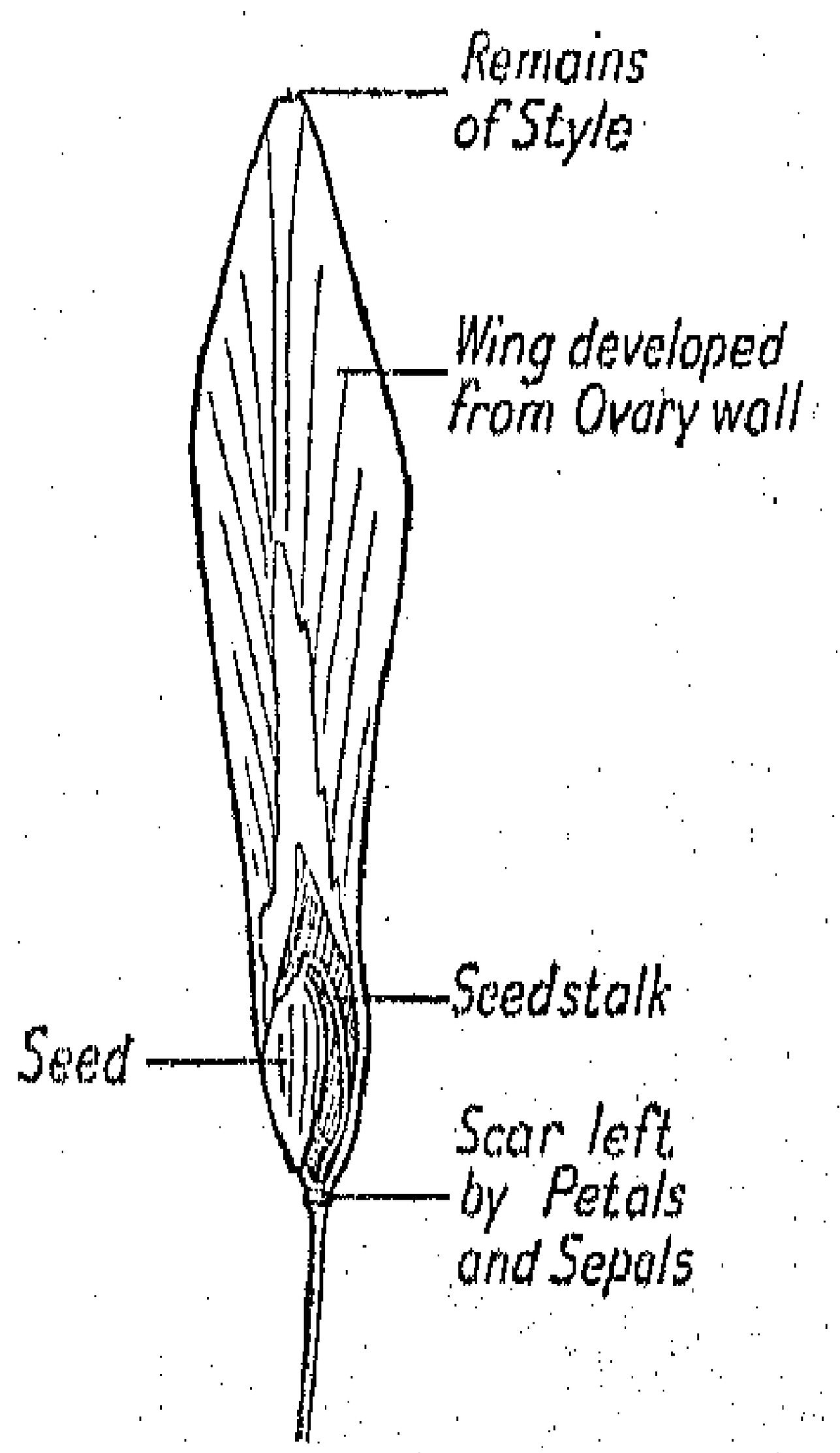
Remains of Style
Wing developed from Ovary wall
Seedstalk
Seed
Scar left by Petals and Sepals

FIG. 125.—Ash fruit dissected to show the seed with its attachment to the ovary wall. (Somewhat enlarged.)

An ash "key" is drawn in Fig. 126*b*. Since it has two scars on it, it ought to be a fruit and should have at least one seed inside it. If you open the swollen part carefully with a needle, you will find a single seed attached by its seed stalk (Fig. 125), so that ash "keys" are in fact fruits. The same is true of

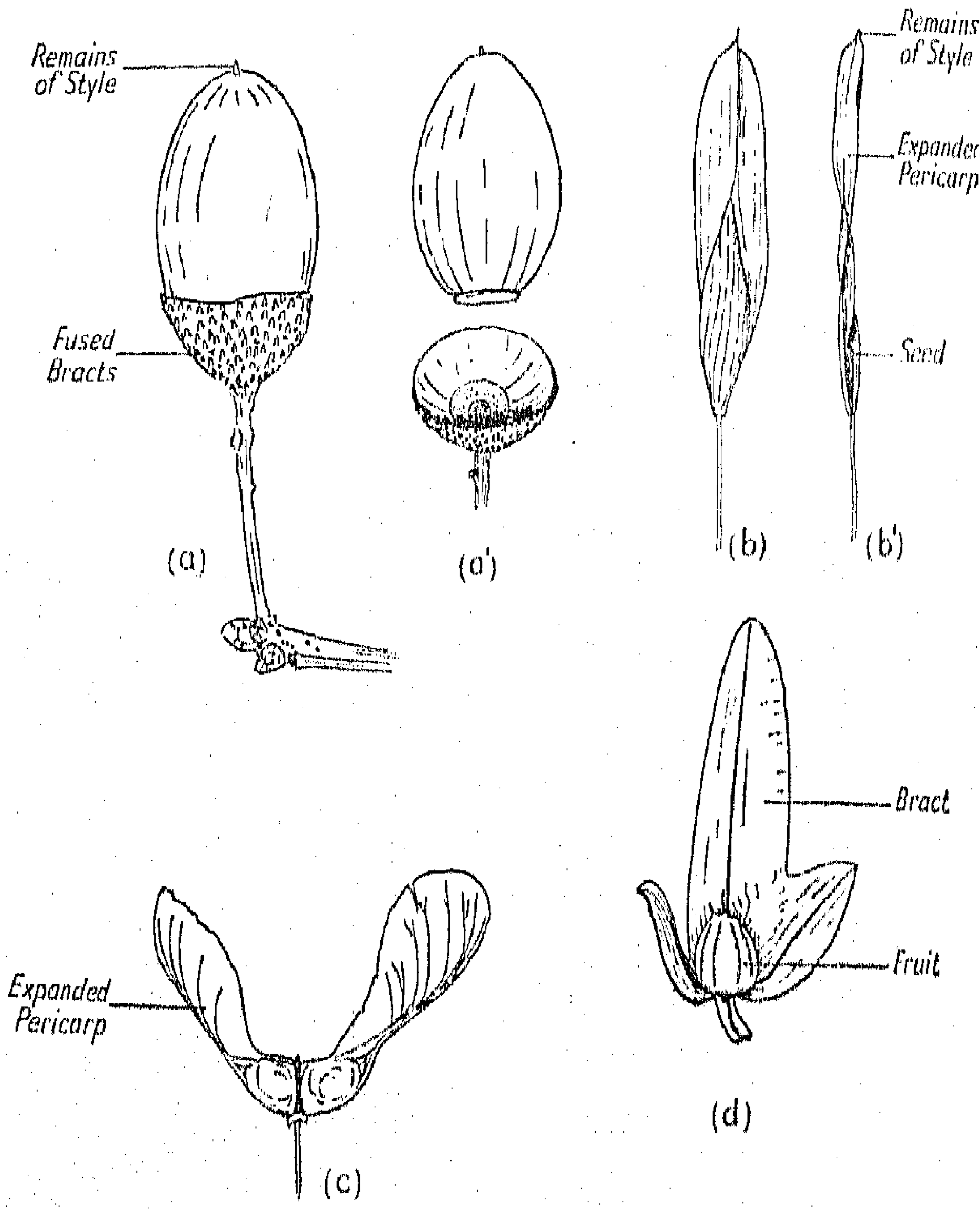

FIG. 126.—Fruit of various trees. (*a*) acorn in its cupule of fused bracts; (*a'*) acorn removed from the cupule of bracts; (*b*) and (*b'*) two views of an ash "key"; (*c*) "boat" of sycamore; (*d*) nut of hornbean with its three-lobed bract. (All × 1.)

sycamore "boats" (Fig. 126*c*). Acorns also are fruit. At one end is a tiny point, the remains of the style, while at the other is a rounded scar where the acorn fitted into its cup (Fig. 126*a'*).

A "conker" shows only one scar and so must be a seed. The fruit it comes from is fairly familiar to most people—it is a spiky green structure which readily splits into three parts to liberate one—or sometimes two—"conkers" (Fig. 148). Wheat, and other grass "seeds" are actually fruits, but in the fruit of plants belonging to the grass family the ovary wall is joined tightly on to the wall of the seed. Such fruits are called "grains".

We must now examine the structure of seeds in a little more detail. Probably the most convenient example to study is the broad bean, for these seeds are large and easy to obtain. You should soak the dry seeds in water for twenty-four hours before examining them, and you will notice that they absorb a good deal of water and expand considerably.

In addition to examining soaked beans, you should plant a few in the garden. Sow the seeds about the beginning of March, 3 inches deep, and leave the plants to flower and produce pods. They usually mature sometime in June. The bean pod is the fruit and inside it will be several bean seeds attached to the wall of the ovary by short seed stalks.

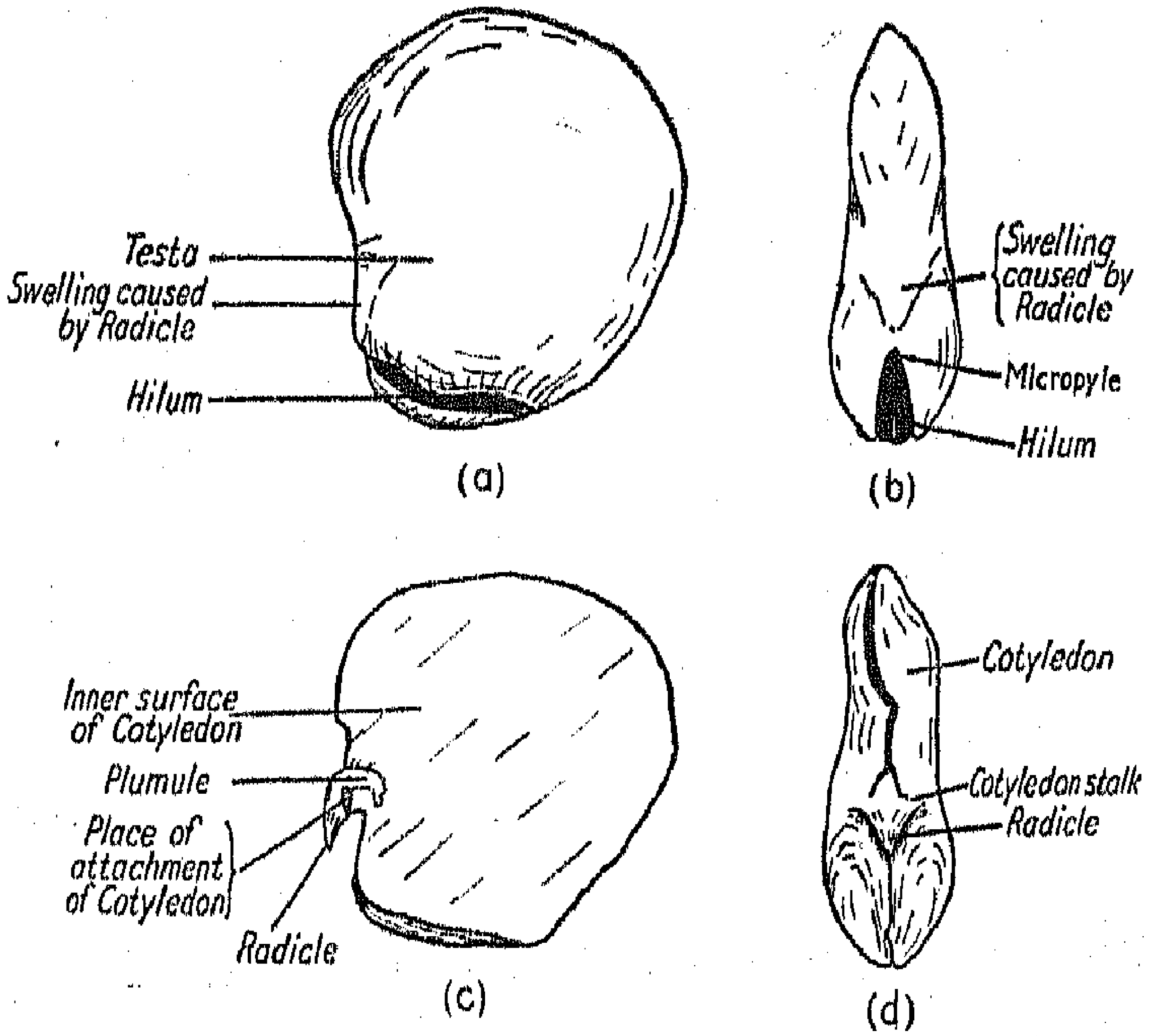
Testa
Swelling caused by Radicle
Hilum
(a)
Swelling caused by Radicle
Micropyle
Hilum
(b)
Inner surface of Cotyledon
Plumule
Place of attachment of Cotyledon
Radicle
(c)
Cotyledon
Cotyledon stalk
Radicle
(d)

FIG. 127.—The Broad Bean seed. (*a*) soaked seed, from the side; (*b*) soaked seed, end view; (*d*) the same, with the seed coat removed; (*c*) one cotyledon, drawn after the other has been detached. (All × 1.)

A soaked bean seed is a plump firm structure flattened from side to side and covered with a rather velvety seed coat. On one edge is a long narrow scar, usually black in colour. This is the *hilum* where the seed stalk was attached to the seed. In occasional specimens the seed stalk may still be fastened to the hilum.

At one end of the hilum is a tiny hole in the seed coat called the *micropyle* (Fig. 127*b*). If it is not easily visible, squeeze the seed gently and a little mass of frothy bubbles will exude. A short distance away is a conical swelling with the point directed towards the micropyle. This is caused by the *radicle*, a structure lying underneath the seed coat (Fig. 127*d*).

Now strip off the seed coat, being careful not to tear it in the region of the micropyle and radicle. Underneath it you will find a creamy white structure which is an undeveloped bean plant. The radicle will now be distinctly visible projecting somewhat on one side.

Look at the seed coat from its inside and you will find that just below the micropyle there is a little pocket into which the tip of the radicle fitted before the seed coat was removed.

A brief inspection will show that the creamy white mass consists of two flattened parts which are joined together only where the radicle comes from between them. Press them apart and separate them completely. This will probably cause the radicle to split down the middle.

Each of the flat pieces is called a cotyledon or seed leaf (see p. 20) and should have attached to it a portion of the radicle. From where it joins the cotyledons the radicle is continued into a pale yellowish green structure which lies between the two cotyledons. This is called the *plumule* and would normally grow into the overground structures of the plant. It is not as a rule split into two halves when the cotyledons are separated, so that the whole of it usually lies on one cotyledon while there is a groove at the corresponding place on the other cotyledon. With a hand lens you should be able to distinguish traces of leaves at the tip of the plumule.

The cotyledons are full of food, mainly starch, which is used by the young plant to enable it to grow. As the seed germinates, the food in the cotyledons is passed into the plumule and radicle, both of which rapidly increase in length. As this process goes on, the cotyledons become thinner and thinner, and shrivel when all the food has been transferred from them.

A bean seed, then, consists of a young plant made up of (1) a plumule which will grow into the overground shoot, (2) a radicle which grows into the root system, and (3) two seed leaves containing food. The whole is enclosed in a seed coat.

A dry seed is not growing. We say it is dormant. If, however, it is supplied with sufficient water and oxygen, and a suitable temperature, it will then begin to grow—this process is

called germination. In nature, germination usually takes place either in spring or in autumn, because at other times the ground is either too dry or too cold.

The early stages in germination can be studied by soaking a number of bean seeds in water and dissecting individual beans at intervals of a day; but if the seeds are left in water, growth will soon cease, and in warm weather the water will become foul and the seeds will die. To overcome this the seeds can be placed in damp sand and dug up at intervals, but I have found the following method the best.

I take two soaked seeds and pin them one on either side of a piece of board that just fits inside a jam-pot. The board is first covered with a double thickness of white blotting paper, though this is not essential. The seeds are arranged to lie flat against the board. Then I add water until the level touches the bottom of the seeds (Fig. 128). If the pot is kept in a warm place, the seeds will continue to develop for some weeks and may then be planted out in the garden. (I use two seeds in case, as sometimes happens, one fails to develop.)

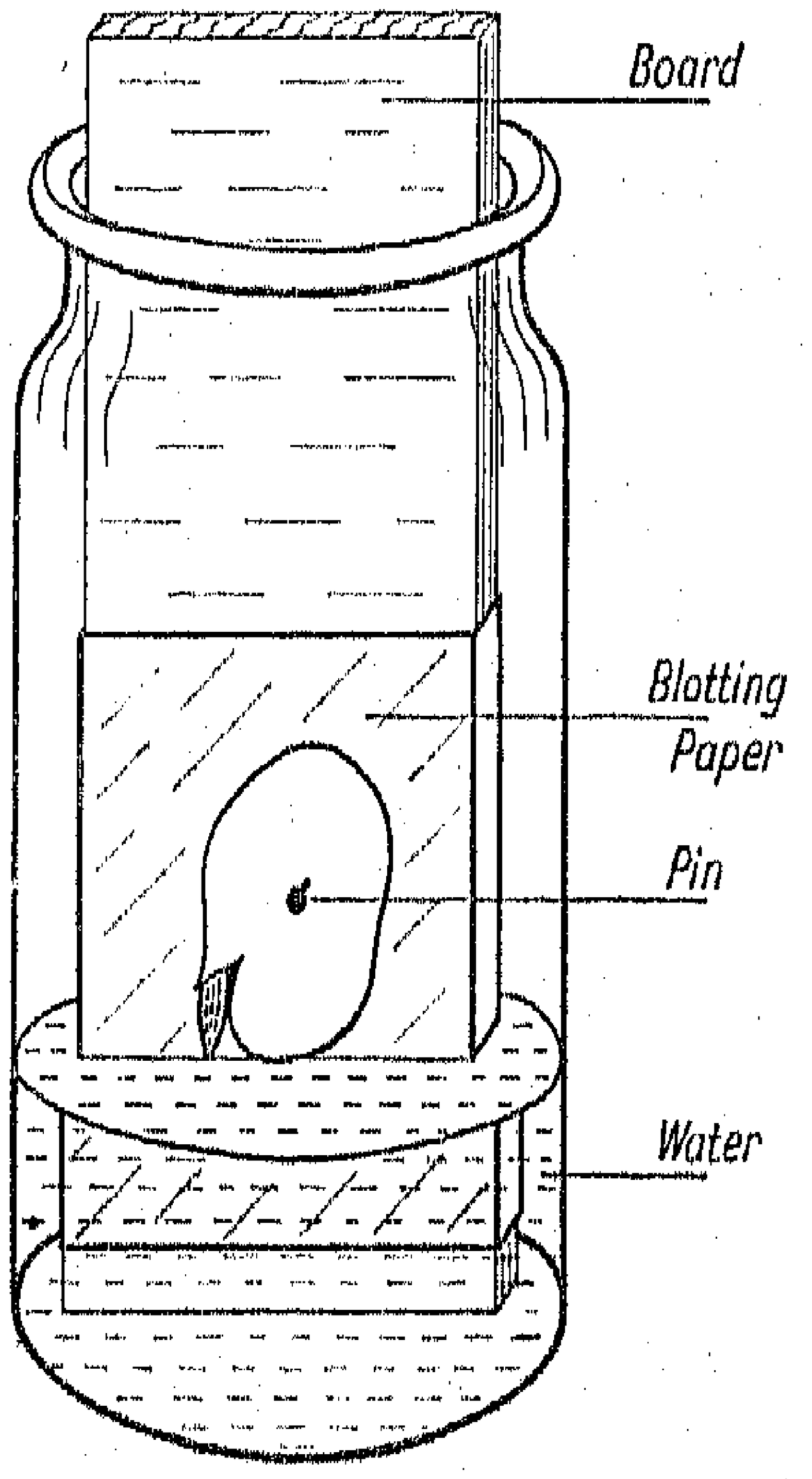

FIG. 128.—Method of growing Broad Bean seed for easy observation.

The first sign of germination after the seed has swollen is the bursting of the radicle through the seed coat. Whichever way the radicle is pointing, it soon turns to grow downwards. Soon the connections between the radicle and the cotyledons lengthen and become visible. These connections are the stalks of the cotyledons, which are really nothing more than much altered leaves. In this way the plumule is withdrawn from between the two cotyledons. It becomes more visible and begins to grow upwards. The young leaves at its tip are now more distinct and the colour becomes a darker green. As the plumule grows upwards it is bent over in a ∩ shape (Fig. 129).

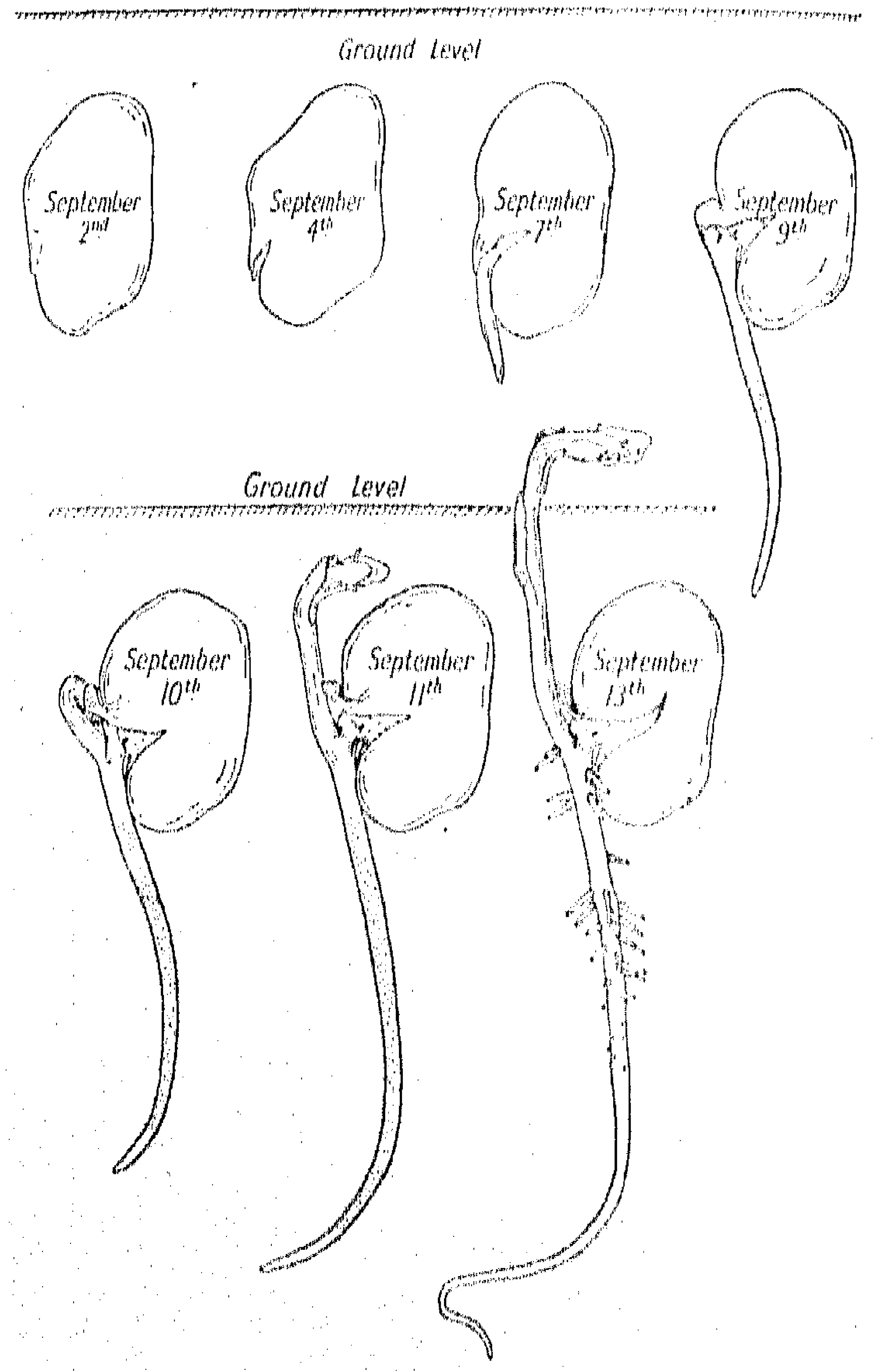

FIG. 129.—Stages in the germination of a Broad Bean seed. The date on which each stage was drawn is printed on the drawings, (×1.)

The importance of this will be clear to you if you remember that normally the plumule would have to force its way through the soil. As the extreme tip is delicate, it would be damaged if it went first. The tougher, older parts are more fitted to push through the soil. After the tip of the plumule has been pulled above ground in this way, the stalk straightens out and the tip is uppermost.

Meanwhile the root continues to grow downwards. After a short time a furry appearance will be noted a short distance behind the root tip. With a hand lens, you will be able to see that this is caused by innumerable tiny white hairs growing from the surface of the root. These are called root hairs and their function is to absorb water and mineral salts for the plant. Root hairs are better seen in mustard seedlings (see below).

When the radicle has grown about 1½ inches long, side roots will begin to appear. These burst their way through the surface of the main root and grow out at an angle. Usually all the side roots make approximately the same angle with the main root. You should also be able to see that the side roots come out in a fairly regular manner, forming four distinct lines along the length of the main root.

The cotyledons of the bean seedling remain below the ground, but, as the food from them is used up by the plant, they become smaller and smaller, and ultimately wither, though this may take from six to ten weeks. By this time, of course, the plant can feed itself.

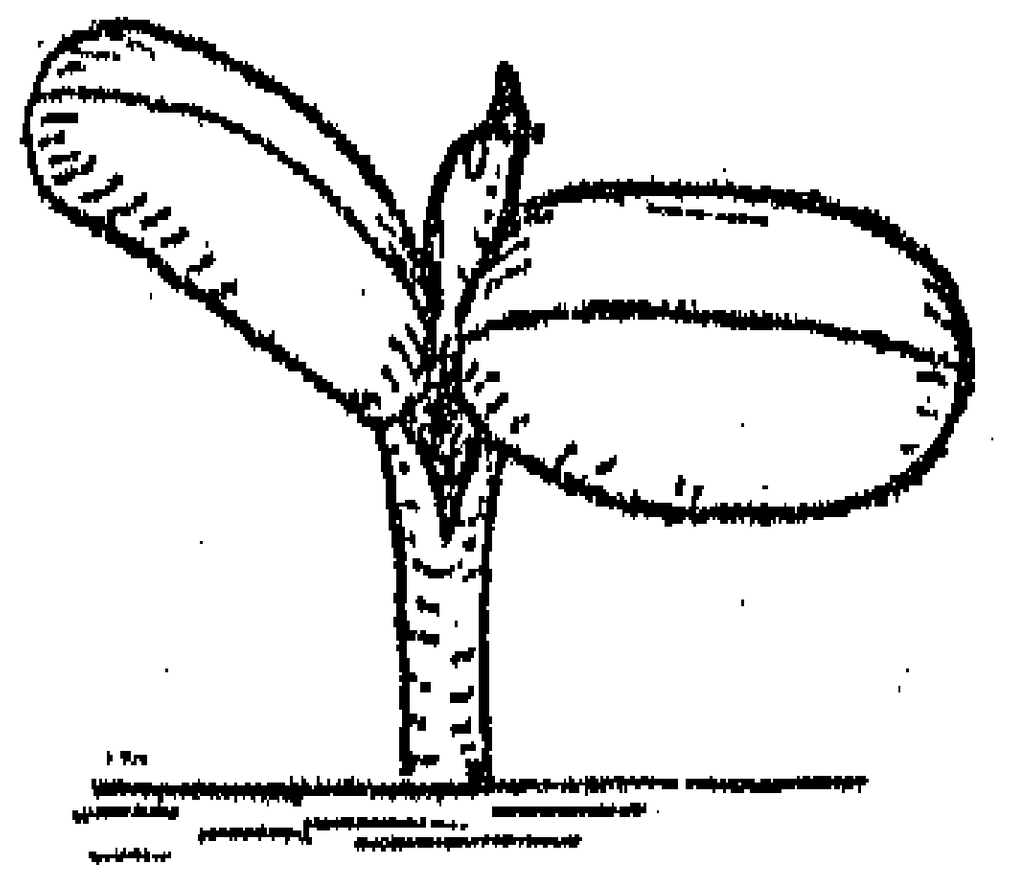

FIG. 130. — Early seedling of Sunflower, showing the two green cotyledons with the plumule between them, (×1.)

Small seeds cannot store so much food as large seeds, hence it is important that the seedlings which arise from them should start making food for themselves as soon as possible. In such seedlings it is usual to find that the cotyledons come above ground, turn green, and carry out the food manufacturing function of normal leaves until these leaves are formed (Fig. 130).

Most seedlings are of this nature and you can observe the habit quite well in mustard, radishes, or any kind of cabbage seedlings. Sow the seeds thinly on moist soil and cover with a thin layer of fine soil. If you use mustard, the seeds germinate in a few days and you should soon see the cotyledons pushing their way above the soil. At first they may be enclosed in the seed coat, but this will soon be shed and the cotyledons will spread out away from one another. Between the cotyledon stalks you will be able to observe the tip of the plumule. As time goes on the plant develops other leaves and the cotyledons, now of less importance, gradually wither away.

Mustard grows quite well on damp cotton wool or blotting-paper placed on a saucer and covered with an inverted jam-pot (Fig. 131). It is a good plan to grow a few mustard seed-

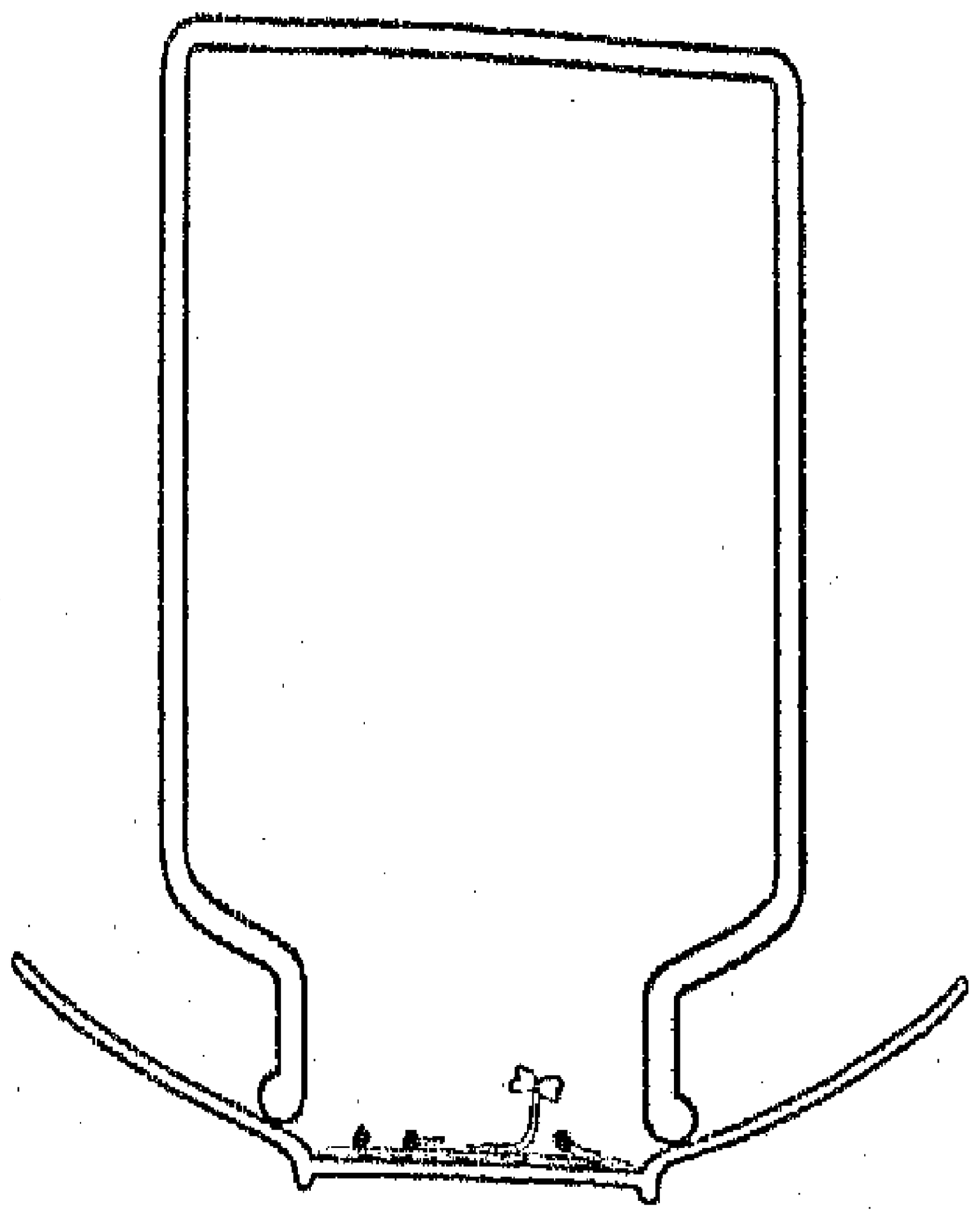

FIG. 131.—Method of growing small seeds on a saucer. There must be some moist absorbent material such as blotting paper or cotton wool on the saucer.

lings in this way, for they demonstrate admirably the development of root hairs.

You may wonder how these young seedlings remain so firmly erect, for they are made of soft material, as you may easily prove by squashing a seedling between your fingers. The answer is that they are made turgid by being filled with water, just as a bicycle tyre or balloon can be made turgid with air. Should a seedling be unable to obtain enough water, it will soon collapse. You can see this for yourself by growing two lots of mustard seedlings in small plant pots. When the seeds have germinated, place both pots together in the light and give one pot a little water each day, but do not water the other. At first the plants in both pots will grow quite well, but, as the soil dries out in the pot that receives no water, the seedlings in it will collapse because their stems will no longer be able to support them.

Root hairs are also kept turgid with water. If you have grown mustard seeds on damp blotting-paper to obtain root hairs (see above), try the effect of holding one of the seedlings in the air. The root hairs will all collapse in a few seconds if the air is dry. They do not collapse in the jam-pot or in the soil because in these places the air is very damp and they do not lose water.

The seeds so far discussed all contain two seed leaves or cotyledons, and for this reason they are called dicotyledons. We have already seen (p. 20) that there is another group of plants called the monocotyledons whose seeds contain only one seed leaf. For the most part these seeds are small and their structure is not easy to see without a microscope. Also, the food is not in the cotyledon but is stored outside the young plant (but, of course, inside the seed coat). The cotyledon has to absorb this food and pass it into the developing plant as germination takes place.

In many monocotyledons the seed leaf remains below ground when the plumule emerges and the first sign of the plumule is a single green spike. This is true of grasses, including Indian Corn (maize).

In other monocotyledons the cotyledon does come above ground carrying with it the seed coat containing what is left of the food supply. The tip of the cotyledon remains inside the seed coat until all the food is absorbed (Fig. 132). You can study this quite well in onions.

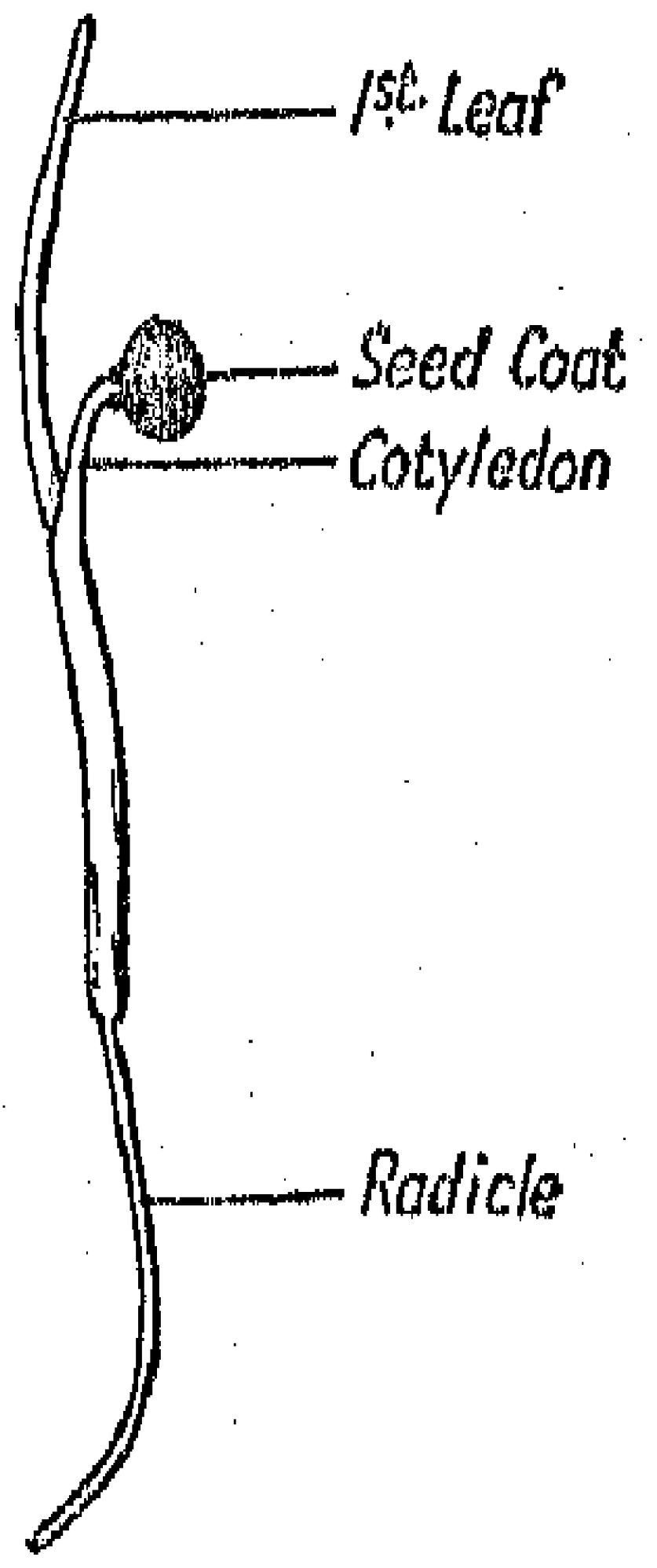

FIG. 132.—Germinating bluebell seedling. The single cotyledon is still absorbing nourishment from inside the seed coat. (×1½.)

Onions take rather a long time to germinate, often as long as ten weeks. However, sow some in the garden about ¼ inch deep, and cover them with fine soil. When the plants do ultimately appear, you will find that they have this kind of shape—∩. Soon one branch of the ∩ will free itself and you will find at its tip the black seed case. Gradually the plant will straighten itself, but for some days the tip of the cotyledon will remain in the seed case. Sooner or later, however, the seed case will fall off, leaving the tip of the cotyledon withered. Other leaves will soon make their appearance.

If you squash one of the black seeds between your thumb-nails, after removing it from the cotyledon tip, you will find that it contains a white substance. This is the food store. Bluebell seeds (Fig. 132) are very similar to onions. In spring, it is possible to find very many bluebell seedlings growing among the litter in bluebell woods.

In coniferous plants (see p. 255) the seeds are not enclosed in an ovary but are formed on the top surface of the scales that form the female cones. Ripe cones of the Scotch Pine can usually be found under trees and generally contain some seeds trapped between the scales. Tear cones to pieces—they are quite tough you will find—until you have several seeds. If pines are not available, other conifers will serve just as well. Each seed is provided with a delicate wing (Fig. 133*a*), but this easily falls off. It is usually not difficult to induce the seeds to germinate either in soil or on damp blotting-paper under a

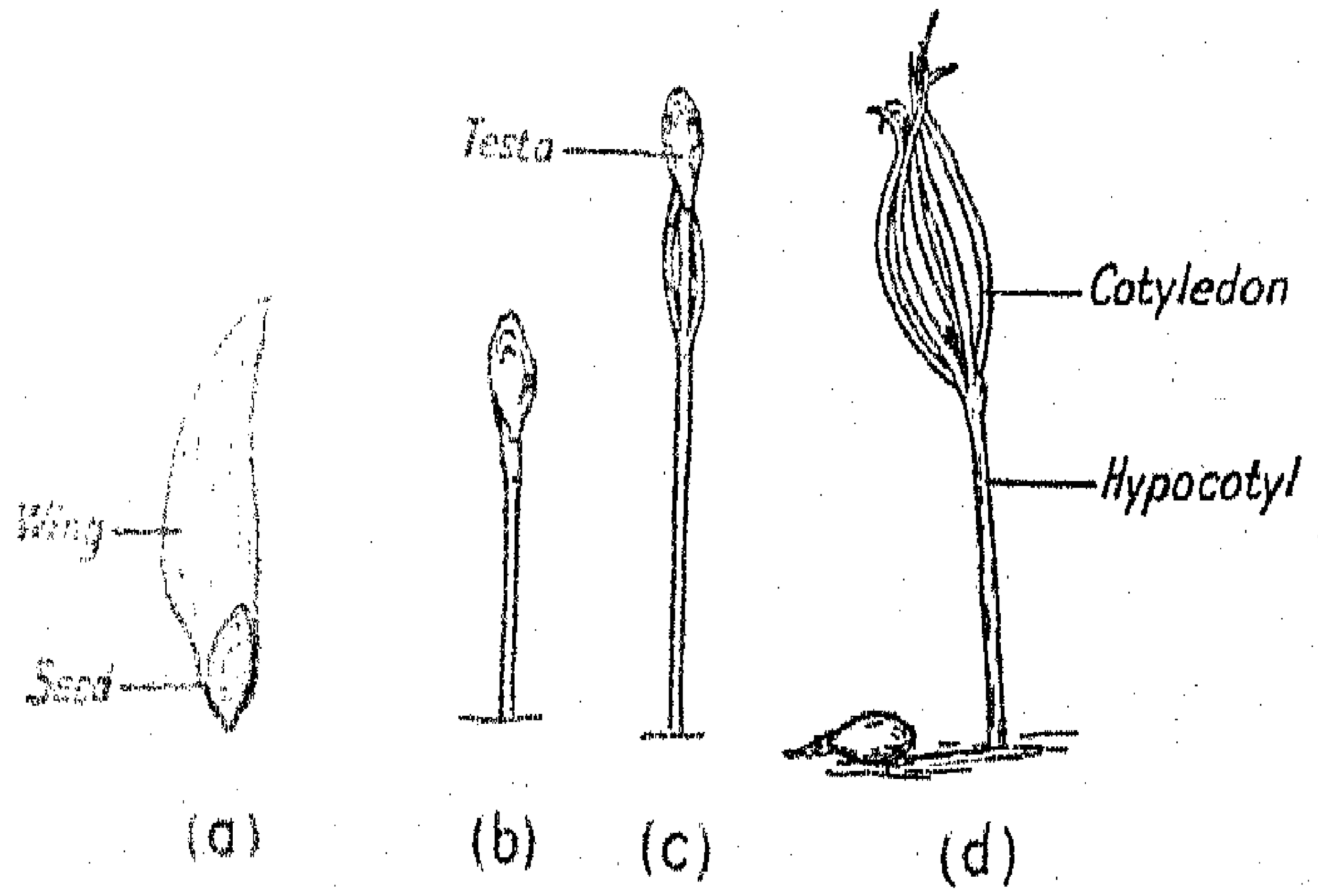

FIG. 133.—Stages in the germination of the seed of the Scotch Pine. (*a*) the seed with its wing; (*b*), (*c*) and (*d*) stages in the germination. Notice that there are six cotyledons in the specimen drawn. (×1⅓.)

jam-pot. You will find that pine seedlings have several cotyledons but that they remain with their tips inside the seed coat for some days. This is because the food is stored outside the cotyledons, as with onions, and they are absorbing food (Fig. 133).

It is worth while to grow seedlings of other trees in pots. Acorns, "conkers", ash "keys" and sycamore "boats", will all grow well. In the case of acorns and conkers the cotyledons remain below ground, but in sycamore and ash and beech they come above ground.

If well cared for, these little trees will continue to grow for several years, especially if you start them in soil taken from woods in which such trees normally grow. In my experience, pine seedlings do not grow so well in pots as other tree seedlings.

CHAPTER TWENTY-FOUR

Insects and Flowers

ONE of the things you must have noticed about flowers is that they are frequently visited by insects such as bees, butterflies, and beetles. Many kinds of flowers almost invariably have small insects crawling about them, as you can easily see by shaking dandelion or convolvulus flowers into the palm of your hand. The convolvulus flowers often contain two or three metallic looking beetles.

Nectar and Pollen

Insects visits flowers to obtain food. One kind of food is the sweet liquid we call NECTAR, which is a solution of sugar made by the flowers in special places called nectaries. You will already have seen the nectaries of the wallflower (p. [illegible])—the dark green horse-shoe shaped patches at the bases of the stamens. In the tulip the ovary wall makes the nectar. If you remove a petal from a buttercup, you will find the nectary near the end where the petal was attached to the flower. It is on the upper surface of the petal and is covered with a flap-like scale. In those flowers that have

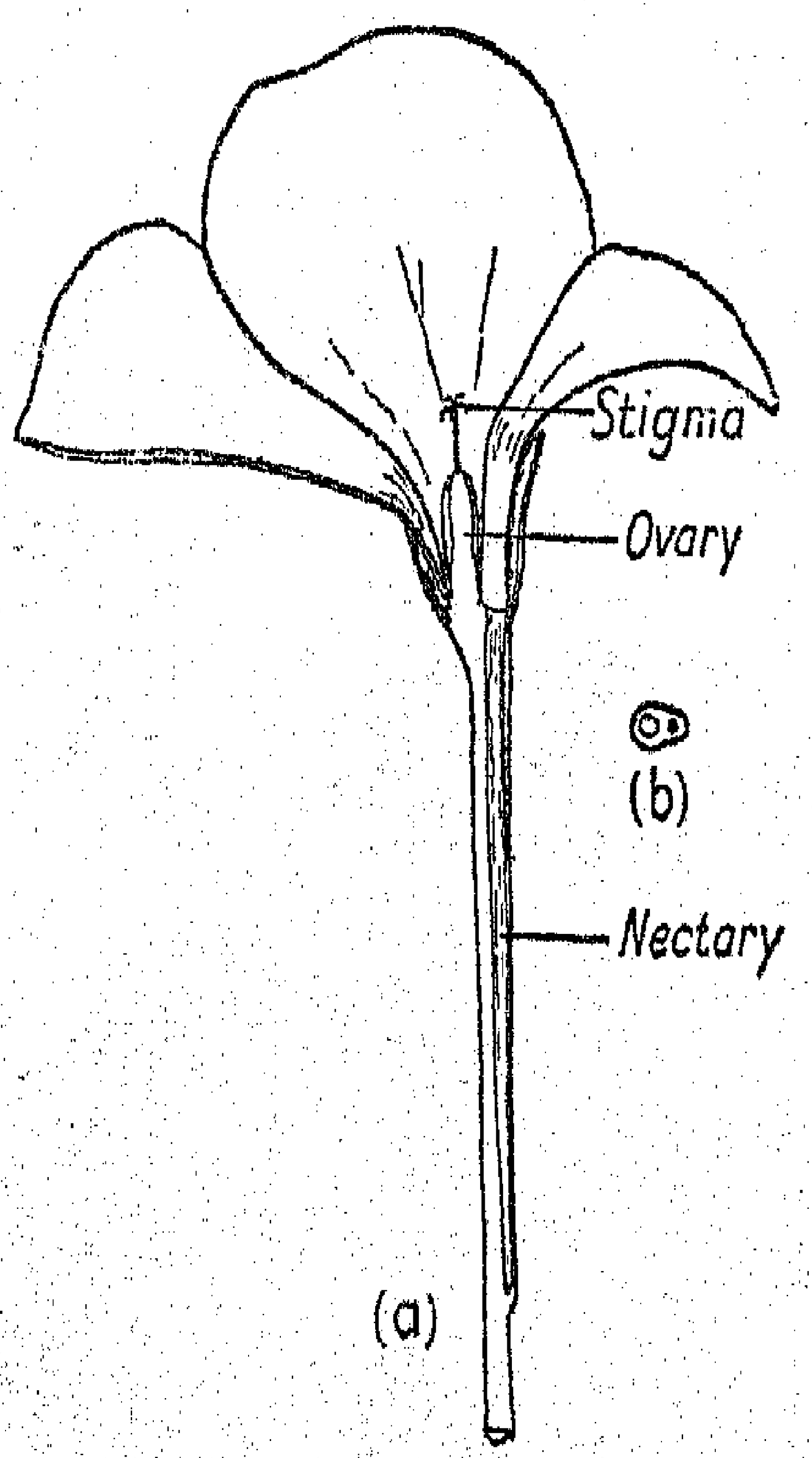

FIG. 134. — (*a*) longitudinal section through a geranium flower to show the nectary; (*b*) cross section through the flower peduncle at the region marked nectary. (×1½.)

spurs (e.g., larkspur, nasturtium, violets) the nectar is usually found at the closed end of the spur, and, under certain weather conditions, may nearly fill the spur. Such plants will give you an opportunity to taste nectar if you split open the spurs. In the ordinary cultivated geranium the nectar is found in a cavity which runs some way down the flower stalk (Fig. 134).

Careful examination of any flower will usually enable the nectar to be found (though sometimes there is none present) because it glistens and looks sticky. You may obtain some help in the search from the flower itself, for on the petals of many flowers are distinct lines, or streaks arranged more or less in lines, which all point to one place. Very frequently the nectar is at this spot, and for this reason these lines are called *guide lines*, for they are supposed to guide insects to the nectar. They are particularly prominent in many of those flowers visited by bees and butterflies in which the nectar is rather hidden. In the geraniums in my garden, the guide lines are much darker red than the scarlet petals, and are especially strongly marked on the two petals that lead down into the cavity containing the nectar. The other three petals have fainter red lines on them.

Guide lines are also well developed on the two top petals and the three top sepals of the nasturtium (Fig. 135) and lead down into the spur which contains the nectar. In flowers such as those mentioned, the guide lines may well be of help to insects searching for nectar. At the same time we must remember that there are other flowers (e.g., larkspur) that secrete honey in rather hidden places and yet have no guide lines. Bumble bees have apparently no difficulty in pushing their tongues in the right place in the spurs of this flower. We must also bear in mind that some poppies have what look like guide lines and yet produce no nectar. Nectar is collected by bees and converted by them into honey, but you must not make the mistake of thinking that nectar and honey are the same thing.

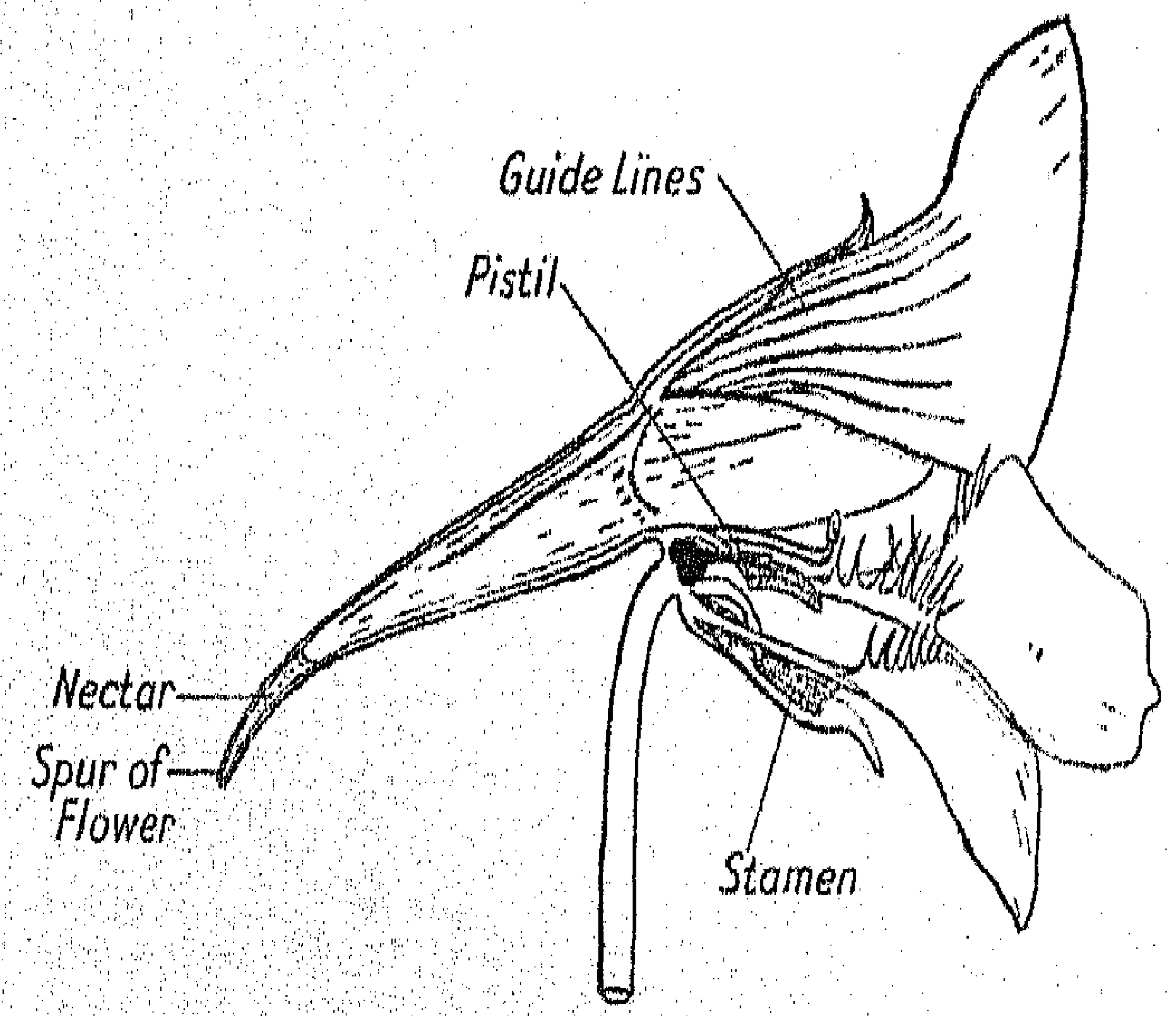

FIG. 135.—Longitudinal section through a young nasturtium flower. (Somewhat enlarged.)

It is clear from the above example of the poppies that all flowers do not produce nectar; in this class are included ordinary garden lupins and the wild rose. The flowers that *do* produce nectar may do so only at certain times of the day and under certain weather conditions. For instance, the lime trees in towns, which are usually in flower during early July, produce nectar generally in a morning, and, if you observe a lime tree, you will probably find that bees are "working" the flowers busily in the mornings but not later in the day. The same is true of other plants; and it is interesting, as you go about, to see which plants the bees are "working" in your area. Weather conditions have a great influence upon nectar production and often flowers produce none for several days.

Insects also visit flowers to obtain POLLEN, which for many insects is their only nitrogen-containing food. Pollen is made in the stamens of the flowers (see p. 18) and its real purpose, you will remember, is to enable the flower to reproduce itself, because it is only after the pollen has fallen on the stigma and grown a pollen tube from there into the flower's ovary that the production of fertile seed becomes possible (see p. 19). However, pollen forms a suitable food for many kinds of insects, just as the seeds (e.g., peas and beans) do for us. Bees, both hive and bumble, collect the pollen in the pollen baskets of their back legs (Fig. 67) and store it in their nests. Besides being used as a food for the larvæ, it is mixed with the wax cappings over the cells in which the larvæ are sealed to complete their development into bees. This mixture of pollen and wax is porous and allows the larvæ to obtain oxygen from the air. Pure wax would not allow air to pass.

On a pollen collecting trip, hive bees will visit only one species of flower, so the pollen in one load is all of the same kind, whereas bumble bees will visit several different kinds of flowers, as you may easily observe for yourself if you watch bumble bees foraging or if you catch and kill a bumble bee and examine the pollen masses in its pollen baskets.

Flowers visited by insects usually have some fairly obvious means of attracting the insects' attention. The flowers may have brightly coloured petals, and sometimes the sepals may also be brightly coloured (e.g., nasturtium). If a single flower is large and brightly coloured, as a tulip or wall-flower, the insects have no difficulty in seeing it from a distance. In many instances, however, each individual flower is quite small, but many are grouped together so that the total result is quite

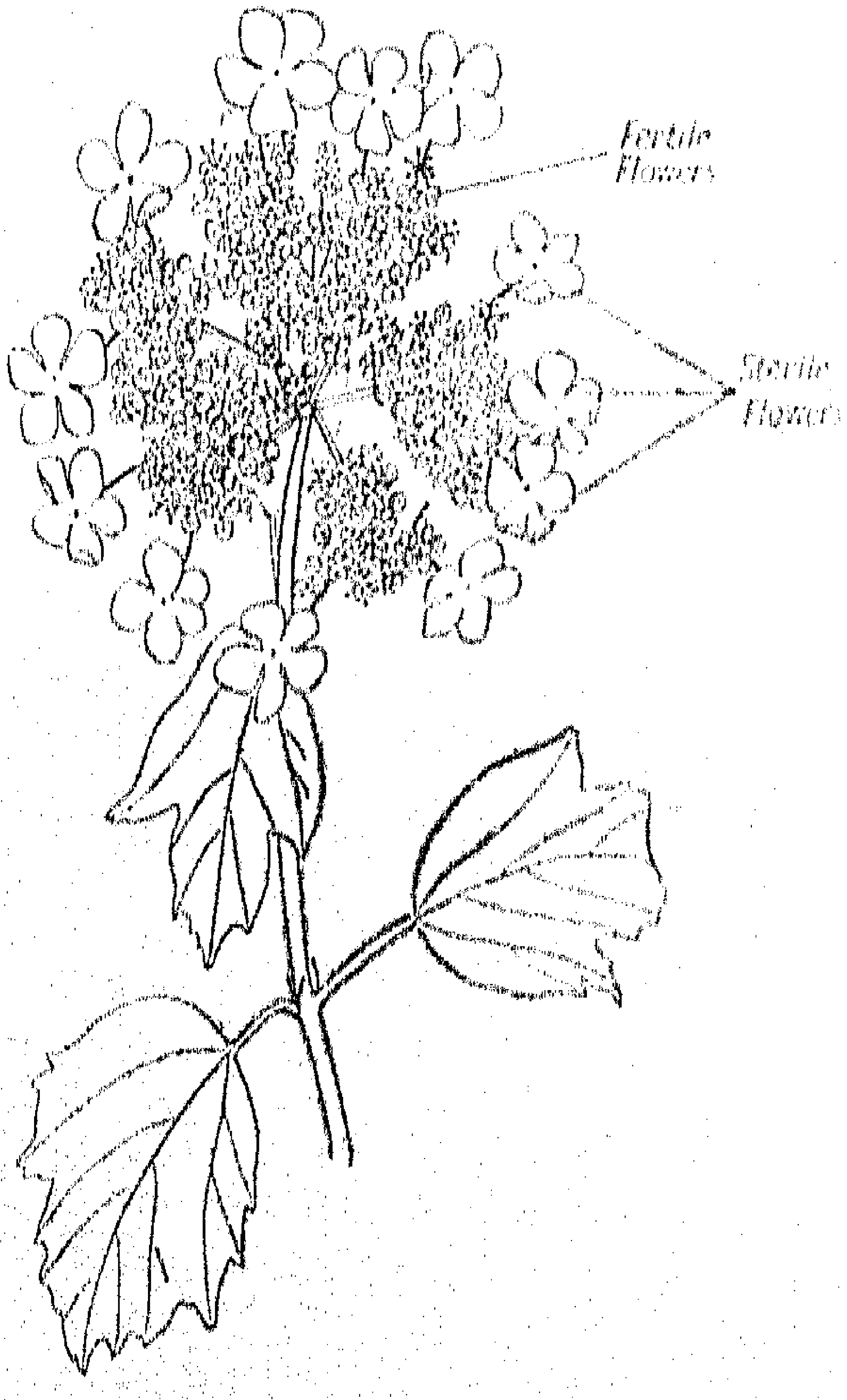

FIG. 136.—Spray of Guelder Rose. The showy but sterile flowers around the outside serve to attract insects, while the inconspicuous flowers in the centre produce the seeds. (× ½.)

conspicuous. An example of this is the forget-me-not of gardens, or the common hedgerow plant, hedge parsley. All members of the Composite group are good examples, and in some members of this group (e.g., the daisy-like flowers, see p. 25), the outer flowers in the collection have their petals drawn out into long brightly coloured strap-like tongues, whereas the petals of the inner flowers are not very large. Some plants, such as the guelder rose, have special flowers, with showy petals but no reproductive organs, placed around a cluster of smaller flowers that do contain reproductive organs (Fig. 136).

In some flowers scent plays a large part in attracting insects; and, of course, many flowers have both perfume and brightly coloured petals, though it is not unusual to find the scent without the bright petals or the bright petals without the scent. I myself can detect no scent in tulips, for instance, while mignonette (both cultivated and wild) is an example of a plant having a strong scent but no brightly coloured petals. Many of the flowers visited by night-flying moths have a strong scent combined with white or yellowish flowers which show up to a surprising degree in the dim light of summer nights. The tobacco plant (Fig. 137) has white flowers and a very sweet scent which is especially strong in the evening. It is on this account often grown in town gardens, and is visited by moths. The large flowered ornamental honeysuckle has yellowish flowers and its scent also becomes most strong in the evening. It is visited by various insects including several of the hawk moths, though some of the hawk moths visit it during the day.

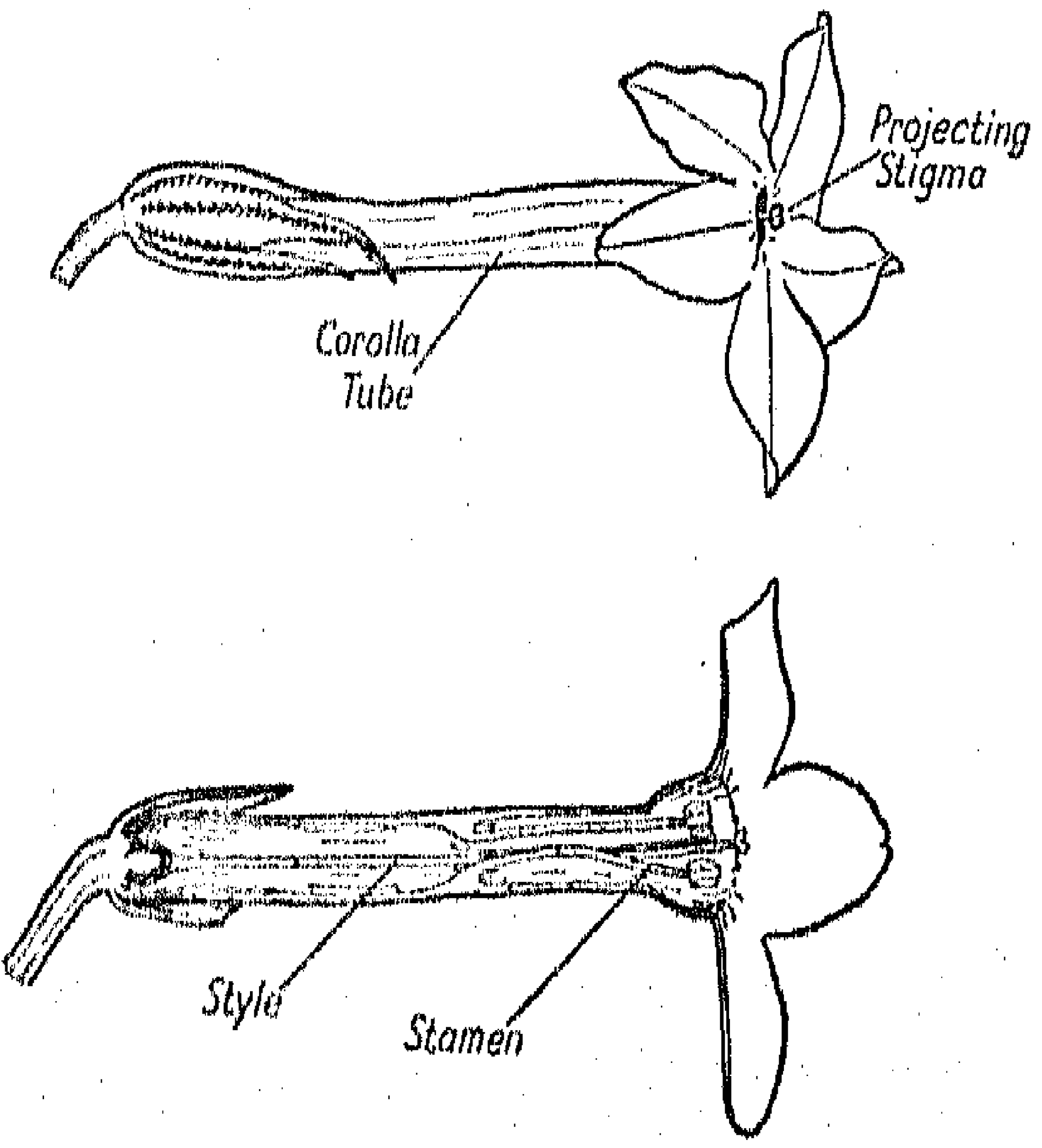

FIG. 137.—Tobacco flower, adapted to pollination by long tongued insects.

Pollination

The flowers supply insects with pollen and nectar; but these are not really free gifts, because matters are so arranged that while they are obtaining these foods, the insects usually perform a service to the flowers. The service is that of pollination, which is the carrying of pollen from stamens to stigmas.

There are two other common methods by which pollination can be brought about: the first is by the plant itself, and the second is by means of the wind.

Self-pollination occurs when the pollen from the stamens of a particular flower is deposited on the stigmas of the same flower. Some plants, e.g., the garden pea and the bee orchid, are normally self-pollinated. Other plants may be self-pollinated if they fail to be cross-pollinated, that is if pollen is not brought to them in some way from another flower.

In grasses, many trees, and some other flowers, the pollen is carried by the wind from the stamens of one flower to the stigmas of another. Such wind-pollinated flowers [e.g., grasses (Fig. 12) and nettles] are inconspicuous and do not produce nectar, neither have they any scent. The stigmas are usually feathery so as to increase their chances of catching air-borne pollen. The pollen is smooth and forms a fine powder the grains of which do not stick together. Grass pollen, or pollen from hazel catkins or pine trees, shows this non-sticky character quite well.

It is not every kind of insect that visits flowers, e.g., dragonflies, grasshoppers, and very many different kinds of beetles, do not. Bees, butterflies and moths, certain of the two-winged flies, and certain kinds of beetles are the commonest visitors. These may be divided into two groups; those with long tongues and those with short tongues. The long-tongued insects are the bees, butterflies, and moths, while the short-tongued ones are most of the two-winged flies, the beetles, and wasps. Some hawk moths have very long tongues indeed, while the tongues of bumble bees, although of different lengths in different species, are longer than the tongues of hive bees. We have seen (p. 127) that the tongues of butterflies and moths are curled in a spiral underneath their heads, and, in live or freshly killed specimens, can be extended by means of a needle.

In general, it is easy enough when looking at a flower to decide whether it is likely to be visited by long tongued or short tongued insects. Those visited by short tongued insects usually have their petals not joined to one another, and have an open basin-like shape with the nectar rather freely exposed, whereas flowers visited by long tongued insects frequently have the nectar rather hidden. Quite often in these flowers the nectar is at the far end of a narrow tube (called a spur) made from parts of the petals or sepals or both. Examples of this are provided by the garden nasturtium (Fig. 135), the delphinium, columbine, and viola.

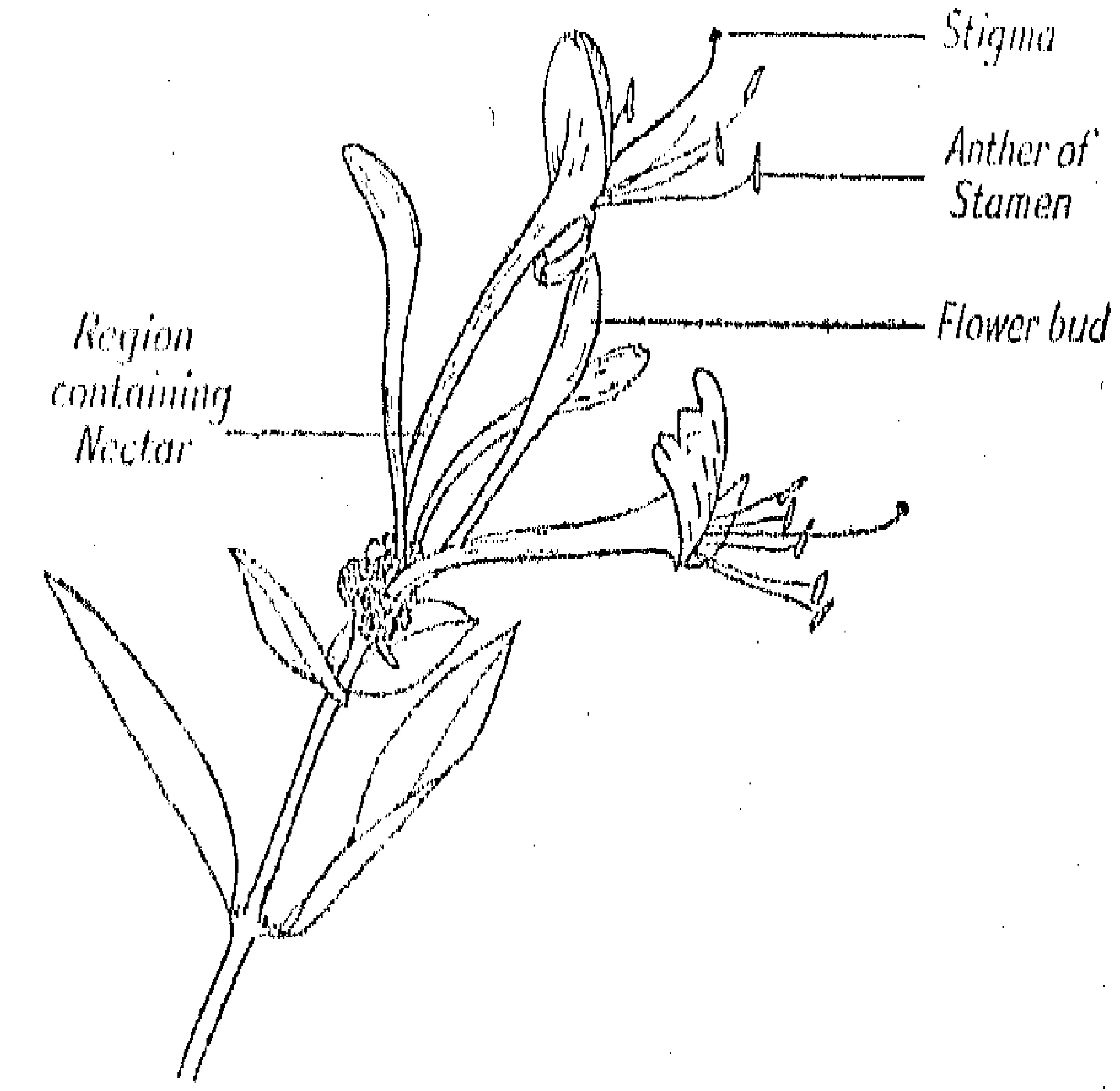

FIG. 138.—Honeysuckle flowers, to show the projecting stigmas and anthers, $\times \frac{2}{3}$. The honeysuckle is pollinated by hawkmoths and hoverflies.

In flowers visited by long-tongued insects the petals may be so shaped that there is only one way into the flower (e.g., the dead nettles, snapdragon, and pea-flower family), and for those flowers visited only by bumble bees the flower may be quite closed and have to be forced open by the visiting insect. Snapdragons are good examples and the only insects you will see visiting them are bumble bees.

In some instances the visiting insect does not alight on the flower but hovers in front of it. Then, as the insect hangs poised in the air it extends its tongue and pushes it into the flower to suck the nectar. This is how the Humming Bird Hawk Moth obtains nectar from the honeysuckle. If the honeysuckle had its stamens and stigmas inside the tube formed by the petals, as flowers usually have, the moth would be unable to transfer pollen from one flower to another. In fact, the stamens and stigmas of honeysuckle project from the flower a short distance and so the pollen can be dusted on to the head of the moth. When the moth moves to another flower, this pollen will be dusted on to the stigmas if they are in a receptive state. In the young flowers the stamens are grouped together in the mouth of the flower with the stigma below them. As the flower becomes older the stigma changes position with the stamens and is thus in a better position to receive pollen from the head of a moth (Fig. 138 should make this clear).

You are possibly wondering why, in many cases, insects do not brush pollen from the stamens of a particular flower on to the stigmas of the same flower. Probably in some flowers they do and self-pollination then occurs. Very often, however, there are special devices which prevent self-pollination.

In some flowers the pollen is incapable of producing ripe seeds if it falls on to the stigmas of the same flower. This is called self-sterility and occurs in that variety of apple known as Cox's Orange Pippin. Flowers of Cox's Orange Pippin will produce apples only if pollen from a different variety of apple is brought to their stigmas. It is for this reason that apple growers never plant an orchard consisting only of Cox's Orange Pippins but always include other varieties. For this reason, also, a good population of bees is desirable in such an orchard, for hive bees are the most important insects for carrying pollen from one apple flower to another.

The majority of plants are not self-sterile; their own pollen, if it falls on their stigmas, is effective in producing seeds, though the plants growing from such seeds are not, in general, as vigorous as those resulting from cross pollination. However, most self-fertile plants have devices which tend to prevent self-pollination. The commonest is to have the stamens ripening and shedding pollen some time before the stigma becomes receptive (i.e., before it will allow pollen to stick to it and grow down into the ovary). This is so in the nasturtium. When a nasturtium flower first opens, the eight stamens are bent downwards and their anthers lie along the bottom petal. The stigma at the end of the style is also bent downwards (Fig. 139).

Soon the filament of one of the stamens begins to bend upwards and this brings the anther into the mid-line of the flower. The anther now points upwards and is in such a position that

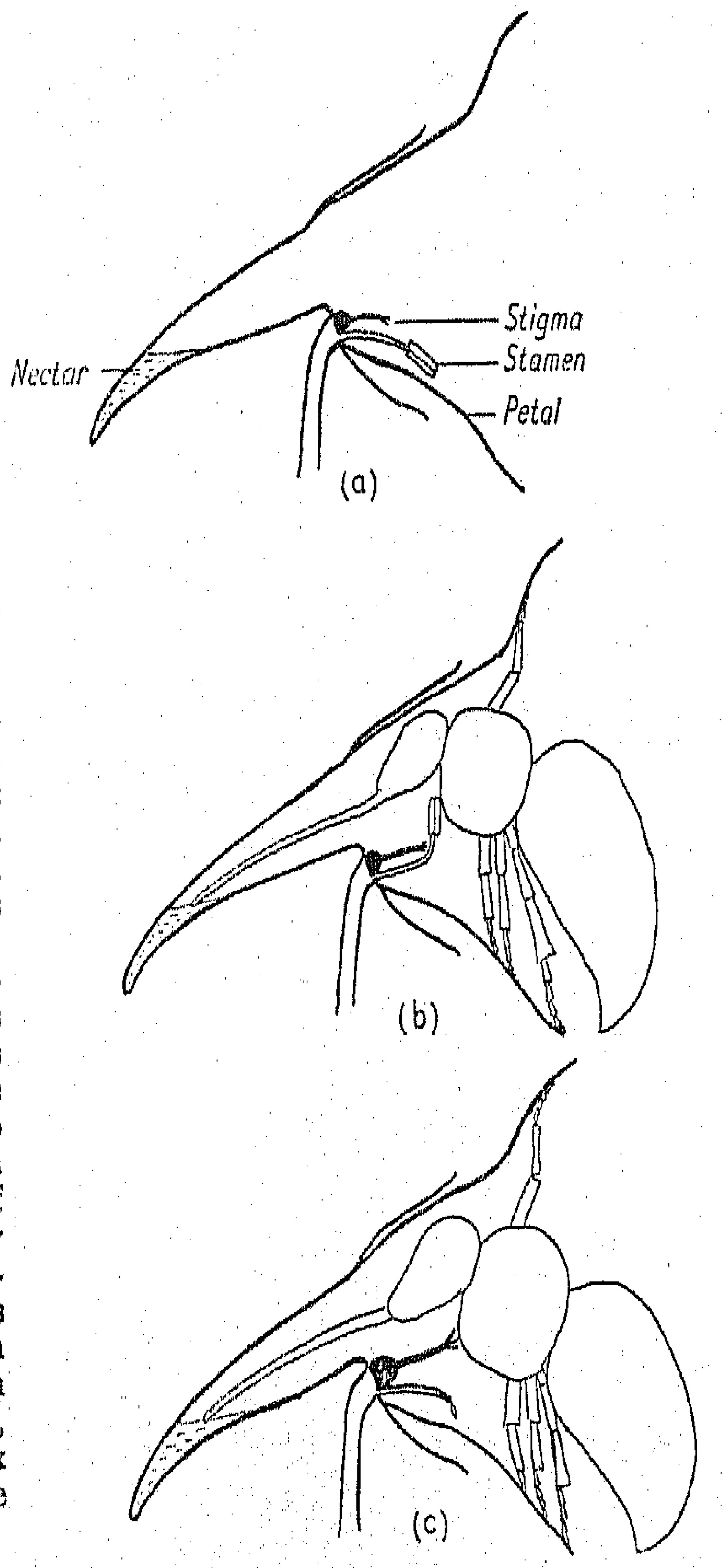

Fig. 139.—Pollination mechanism of the nasturtium. (*a*) newly opened flower, with the stigma and the eight stamens both bent away from the throat of the flower; (*b*) one of the stamens has turned upwards, and now occupies a position in the throat of the flower, where it is likely to rub pollen on the thorax of a bumble bee (*Bombus hortorum*) attempting to obtain nectar; (*c*) when the stamen in (*b*) has shed its pollen, it bends downwards out of the way, and another stamen goes through this cycle; ultimately, the stigma bends upwards and its three lobes separate from one another and come to occupy the position in the throat of the flower previously occupied by the stamens. The stigma is now in a position to receive pollen from another flower, carried on the thorax of a visiting bumble bee.

a bumble bee seeking to obtain the nectar from the spur must brush against it and so get dusted with pollen. When this anther has shed its pollen and withered, the filament bends down again. Another stamen then acts in the same way, bending upwards to bring its anther into the mid-line of the flower. This process continues until all the stamens have in turn moved up, liberated their pollen, and moved out of the way again. Now the stigma is mature and is moved upwards by the style, so that it comes to occupy exactly the place previously occupied by the anthers. In this position it is well placed to receive pollen from bumble bees that have come from other nasturtium flowers still in the earlier stages, and so cross-pollination is brought about. Self-pollination by pollen dropping on to the stigmas is prevented because of the structure of the stigma. This is divided into three lobes, but only the inner faces of the lobes are receptive. Until the stigma moves up into the central line of the flower, the three lobes remain with their receptive faces pressed together (Fig. 139 *a* and *b*). The whole process in the nasturtium is completed in rather less than a week and is easy to follow if you observe a marked flower each day in the morning and evening. On the other hand, if you examine a number of flowers of different ages, you should be able to see all the stages. Many other flowers have similar movements of their stamens and stigmas (e.g., honeysuckle, fire-weed).

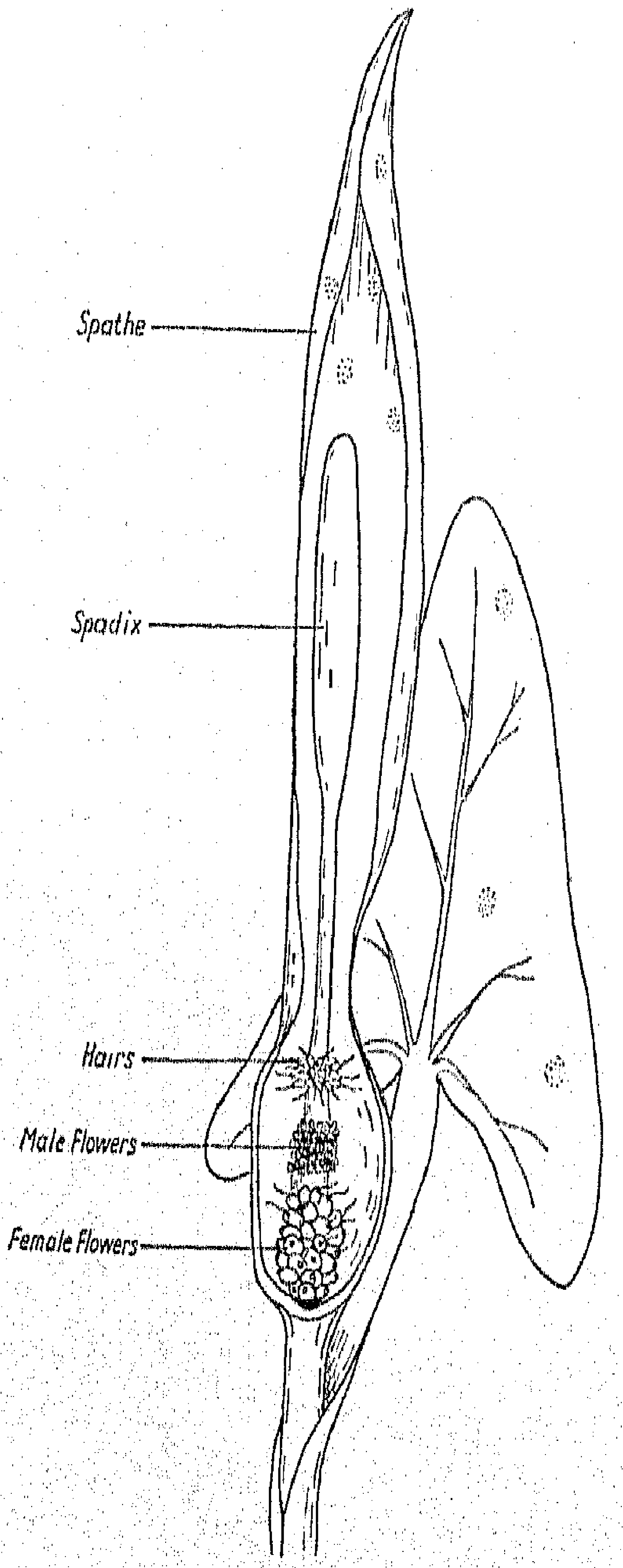

FIG. 140.—Inflorescence of wild arum (*Arum maculatum*). The lower part of the bulb formed by the spathe has been cut away to expose the flowers, ×½.

The arrangement obtaining in some flowers, where the stigmas become receptive before the pollen is ripe, is even more certain to prevent self-pollination. This device is rarer than the one previously discussed, but the wild arum is a common plant that shows it very well. This plant grows abundantly in damp situations, in hedgerows and mixed woods. The broad arrow-shaped leaves with large blotches of brownish-purple are easily recognised in spring. The "flower" is not really a single flower but a whole flowering branch consisting of many individual flowers wrapped around by a large leaf-like structure called the spathe. The end of the flowering branch is swollen into a pinkish-purple cylinder called the spadix. If you cut a slice from the side of the flask-like base of the spathe, the flowers will be clearly visible (Fig. 140). A sharp knife or razor blade will do this conveniently.

The positions of the various structures are shown in Fig. 140. Nearest the base are the female flowers clustered tightly round the central axis. A short distance above them is a cluster of male flowers. Higher up still are several rings of hairs thickened at their bases in such a way that they will bend downwards but not upwards. The tips of these hairs touch the inner wall of the spathe. The hairs act as a kind of trap for they will allow small insects to pass downwards into the cavity formed by the base of the spathe, but not upwards. So once an insect enters the cavity it cannot easily escape until the hairs wither.

When the arum "flower" first opens, small flies are attracted to it, possibly because of the colour of the spathe and possibly by the smell, which is said to resemble that of rotting meat. I cannot detect any smell myself, but other persons say they can. However, flies are undoubtedly attracted and find their way into the cavity, where, as explained above, they become captives. The stigmas ripen first, and if the insects are carrying on their hairs pollen from other arum plants, as they very likely may be, this will be deposited on the stigmas, and the ovaries will begin to ripen. Each female flower, after pollination, produces a drop of nectar which is sucked up as food by the insects.

The stamens now ripen and shed their pollen, which falls to the bottom of the cavity and thoroughly dusts any insects present. Since the stigmas are no longer capable of being pollinated the plant cannot pollinate itself. Finally the ring of hairs begins to wither and the insects, covered with pollen, make their escape and many of them go to other arum flowers to pollinate them in their turn and enable the process to be repeated.

Figwort (Fig. 141) is another plant in which the stigmas mature before the stamens. The flowers are a deep purple and rather globular and in the young flowers only the stigma protrudes from the flower. On this is dusted pollen brought from another figwort plant, usually by a wasp, and pollination takes place. After a time the stigma shrivels and its place is taken by the four stamens which previously lay hidden inside the flower. Now they project a short distance in front of the flower. Each stamen has a short anther at its free end, and this opens by a slit along its top, exposing the bright yellow pollen in the best position to be brushed off by other wasps visiting the flower. One of the five stamens, the one at the top of the flower, never produces pollen, being reduced to a thin flap or scale, but there is nectar between it and the two petal lobes above it. This modified stamen is called a staminode.

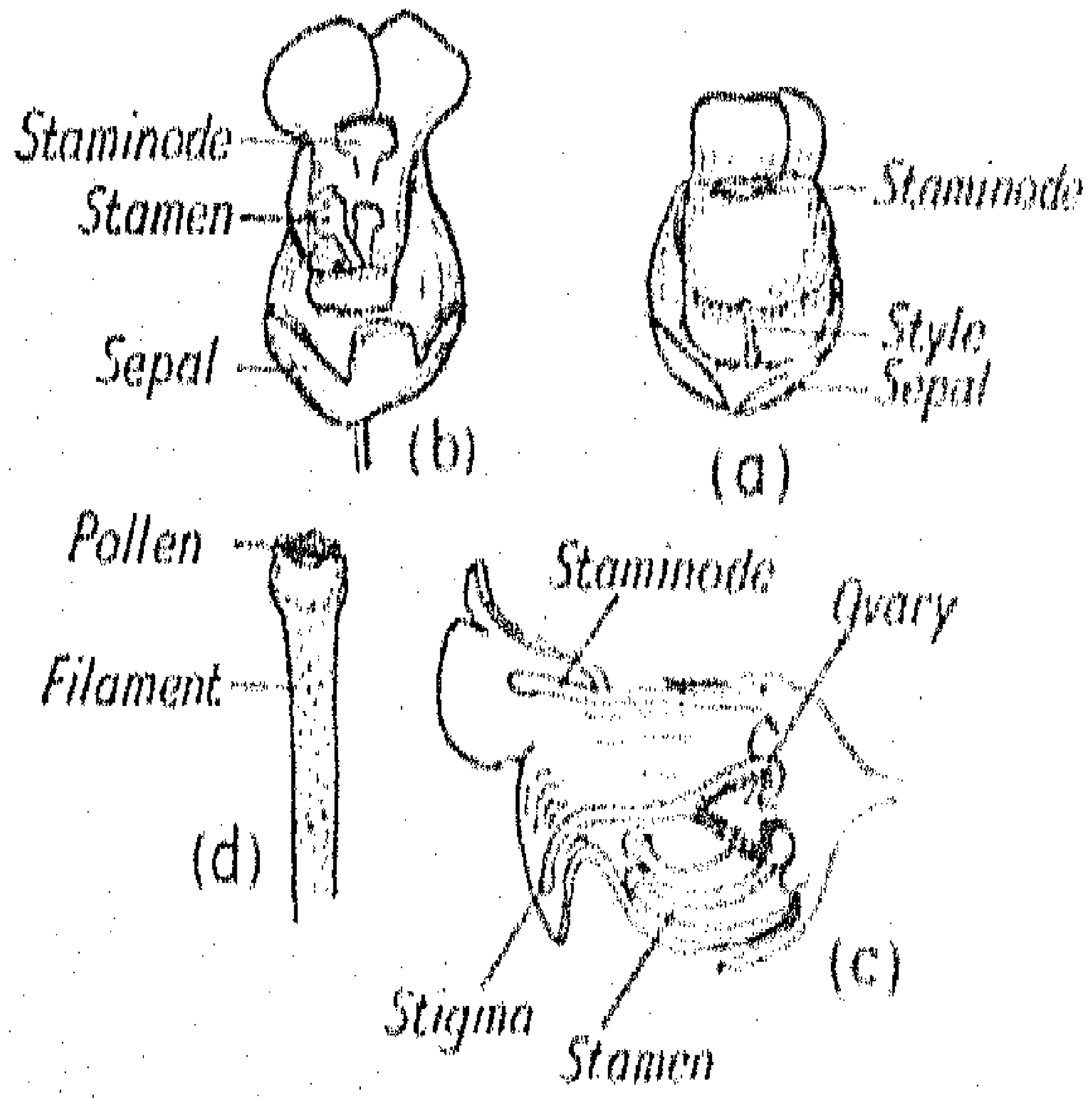

FIG. 141.—Water Figwort (*Scrophularia aquatica*). (*a*) front view of young flower, in the female stage; (*b*) older flower, in the male stage; (*c*) longitudinal section through a young flower; (*d*) a single stamen to show how the anther liberates the pollen by a terminal transverse slit. (*a*), (*b*) and (*c*), × 3; (*d*), ×6.

Although insects, in obtaining the nectar from flowers, usually pollinate those flowers in the process, there are some

instances where this is not so. Very tiny insects (e.g., certain beetles) may crawl down inside a flower and reach the nectary without ever coming into contact with the stigma and stamens. This is unfortunate for the flower, because, if all the nectar is regularly stolen, insects which are capable of pollinating that type of flower might in time cease to visit it as unprofitable. To prevent small insects stealing the nectar in this way, some flowers have the entrance to the nectary protected by stiff hairs or sometimes by scales, while other flowers such as the snapdragon have the whole flower closed so tightly that only the correct insect—in this instance a bumble bee—can open it. The White Dead Nettle (called dead because it cannot sting) is a good example of a flower with a barrier of hairs placed before the nectary. These form a sloping band running round the inside of the tube formed by the petals and are placed a short distance in front of the nectary.

In a few flowers, bumble bees bite through the wall of the flower to reach the nectar instead of obtaining it in the more usual way by entering the flower from the front. You may often see the scarlet flowers (particularly the early ones) of the runner bean bitten in this way, also the flowers of the White Dead Nettle.

By now you will have realised that there is much about the manner in which flowers are pollinated that can be learned by anyone with a sharp pair of eyes and leisure to watch flowers. At all times, in the garden or park, on pieces of waste ground in towns, or in country lanes and fields, you should take an interest in the shape and colour of flowers, and in the kinds of insects to be seen visiting them.

Summary

In this Chapter I have said that many flowers are visited by insects which are attracted by colour or scent, or sometimes by both. It is often possible to guess from its structure whether a particular flower is likely to be visited by long-tongued or short-tongued insects, and observation of the flower will usually enable one to see whether the guess is correct. The insects obtain nectar and pollen from the flower and use these substances as food. Frequently the position of the nectar is indicated by the presence of guide lines on the flower. The insects searching for pollen and nectar perform an important service to flowers by carrying pollen from the stamens to the stigmas.

In some flowers their own pollen, when placed on their stigmas, will produce fertile seeds; but it has been found that, in general, healthier and more sturdy plants are formed from seeds that result from cross-pollination (i.e., when pollen from one plant is placed on the stigmas of a different plant). Many flowers, indeed, have devices to encourage this and prevent self-pollination. These devices include self-sterility (the pollen of a particular plant is then incapable of fertilising the ovules of that same plant); the stamens and stigmas of a plant not ripening at the same time; or the presence of male and female flowers in different plants of a particular kind.

Some flowers are pollinated by the action of wind, and so do not require the help of insects. Such flowers are as a rule easy to recognise, because they are small and inconspicuous, have prominent stigmas that are often feathery, and produce an abundance of powdery pollen. You may be tempted to think that the insect method of pollination is more certain than the wind method, but it must be remembered that grasses, a most successful group of plants, are all wind-pollinated.

CHAPTER TWENTY-FIVE

Trees

Trees as Flowering Plants

WHEN I was a youngster living in a Shropshire village, I was well aware of a real difference between trees and those plants which, for want of a better name, we called "flowers".

"Flowers" were rather low growing plants which, although they disappeared in winter, sometimes grew in the same place year after year—as the bluebells in the oak wood and the primroses along the hedge bank. Other flowers, I knew, grew in the garden for only one year, and, if new plants were required the next season, we had to sow fresh seeds. This was true of sweet peas, larkspur, mignonette, nasturtiums, and several others.

Trees, however, were obviously different, for there they were in the same place year after year. The only change my youthful eyes could detect was that in winter the trees were bare of leaves, and the rooks and wood pigeons in their branches could be seen from a long way off, whereas in summer the leaves obscured the light from the sky.

Into this scheme of trees and "flowers", plants such as grasses, and gooseberry and black currant bushes, fitted rather uneasily. I knew that currant bushes would not grow into trees no matter how long they were left to grow, and yet they resembled trees in some respects. They had woody branches and lost their leaves in winter just as an oak or ash tree. Yet they also had tiny flowers in spring, and at that time I was not used to the idea that trees have flowers. True, I did know that apple trees, pears, cherries, and the wild sloe had flowers, but I had not seen the flowers on the oak, ash, sycamore, birch, elms, and pines. Nor, at that time, had I seen anything on grasses to suggest flowers.

Since then, with closer study, I have come to realise that, after all, trees are only special kinds of flowering plants. The purpose of this chapter is to show you the resemblance between trees and more ordinary "flowers".

Plants can be divided into two groups: those whose stems are made of woody material that can survive the winter, and those with stems of softer material that dies away in winter. The first group we call woody plants, the second herbs.

Some Herbs, such as peas, beans, and nasturtiums, die at the end of one year's growth. They are called *annuals*. Other herbs such as cabbages, onions, beetroot, and carrots, live for two years. During the first year they grow steadily and store food. Growth stops during the winter, but the next spring starts again and the plants now make flowers which soon produce seeds. After the seeds have ripened the plants die. The life cycle thus occupies two growing seasons, and on this account these plants are called *biennials* (not biannuals!) A third kind of herb is that which grows year after year in the same place; although each winter the overground parts die away more or less completely, swollen structures full of food are left below the ground, and these serve to start off next year's growth. Daffodils, tulips, dandelions, lupins, and rhubarb, are of this nature and are called *perennial* herbs.

Woody Perennials are similar to perennial herbs in that one plant grows for many years in the same place; but they differ in that the overground parts do not die away in winter. Instead, they remain without growing until next spring and then, by further growth, add to the parts already present. In this way woody perennials continually increase in size from year to year. Two important kinds of woody perennials are trees and shrubs. Trees grow more than six feet high and do not branch near to the ground. Shrubs are usually less than six feet high and branch near to the ground (e.g., gooseberry, gorse, rhododendrons). The scheme at the top of the next page sums up all this.

FLOWERING PLANTS

- HERBS (made of soft material that dies) in winter)
    - ANNUALS (complete their life cycle in one year)
    - BIENNIALS (complete their life cycle in two years)
    - PERENNIALS (live for many years, usually producing seeds each year)
- WOODY PLANTS (made of hard material that can resist winter)
    - SHRUBS (usually branched near to the ground and less than six feet tall)
    - TREES (more than six feet high, and not branched near to the ground)

Deciduous Trees

The overground parts of a tree consist of the trunk (or bole), which at its top splits up into the branches, which in turn divide to form smaller branches. These finally end in the thinnest branches of all, the twigs. The trunk is continued below ground as the root system. This is always extensive and much branched in order to be able to support the tree. During summer, strong winds blowing on the leaf-laden boughs create such tremendous forces that any tree not securely anchored would soon be uprooted. Also the roots have to be wide-spreading to obtain sufficient water and dissolved substances from the soil. The amount of these substances required is great, and the roots of a tree may impoverish the soil for a considerable distance around the trunk, a fact well known to gardeners. Unlike most other plants, trees do not as a rule have root hairs (see p. 227). Instead, on their root tips they have a tiny network of fungal hyphæ (see p. 49) closely fitting over the root like a thimble, or else actually inside the tissues of the root tip. These fungal threads help the tree to take up water and food substances (see p. 294).

It is possible to identify all the British trees from their winter twigs, which is another way of saying that the winter twigs of trees are all different. Nevertheless, they do have a number of points in common.

The outside "skin" of the tree is the Bark. Bark is made of cork such as you see in an ordinary bottle cork, for these corks are made from the bark of the Cork Oak. Cork or bark is a protective layer through which many enemies of trees, especially fungi, find it difficult to penetrate. One of the reasons why you should not carve your name on the bark of living trees is that by cutting the bark you may let spores of harmful fungi gain entry into the living substance of the tree. The fungi which come from the spores may eventually kill the tree.

On the trunk the bark may be more or less smooth (e.g., beech trees), or it may be thrown into long furrows and ridges (e.g., oak, ash, elm). In plane trees the bark is smooth, but it constantly comes away in large flakes several inches across. The new bark exposed when these flakes come away is light yellow while the old bark is a greenish brown, so that the trunks of plane trees always look rather patchy. However, because of this continual flaking off, the bark never gets really dirty, and this is said to be one of the reasons why plane trees are so often chosen for planting in town streets.

On the finer twigs the bark is always more or less smooth, except that there are numerous tiny raised patches which look as if the bark had been forced up at these points from inside the stem. These patches are called *lenticels* (len-ti-sels) and are really holes passing right through the bark to allow oxygen from the air to pass into the tree. The lenticels can be seen plainly in bottle corks as brownish streaks of soft powdery material running across the cork. The shape and size of the lenticels vary very much from tree to tree. Those of the elderberry are very conspicuous.

On the twigs are borne the BUDS and the LEAVES. The winter buds of most trees are protected by a number of corky bud scales, closely overlapping one another and protecting the delicate structures inside from the danger of drying up. Any particular bud will grow either into a branch or a flower (or, of course, it may not develop at all, in which case it is called a dormant bud).

The winter buds of various trees differ a good deal. Some, such as those of beech, are long and slender, with many bud scales. Others such as those of lime, hazel, and elm, are rather oval in outline with few visible scales. The buds of ash are black, and those of sycamore green. Sometimes (as in ash and horse chestnut) the buds are placed in pairs opposite to one another, whereas in lime they are placed singly on alternate sides of the stem. Some buds (e.g., horse chestnut and poplar) have their scales covered with a gummy substance, while bud scales of some other trees (e.g., apple) are clothed in a felt of downy hairs. There is no purpose in my describing to you the buds of all the various trees. You must take every opportunity of examining the winter twigs of trees and making drawings of them, and soon you will be able to recognise most of them at sight.

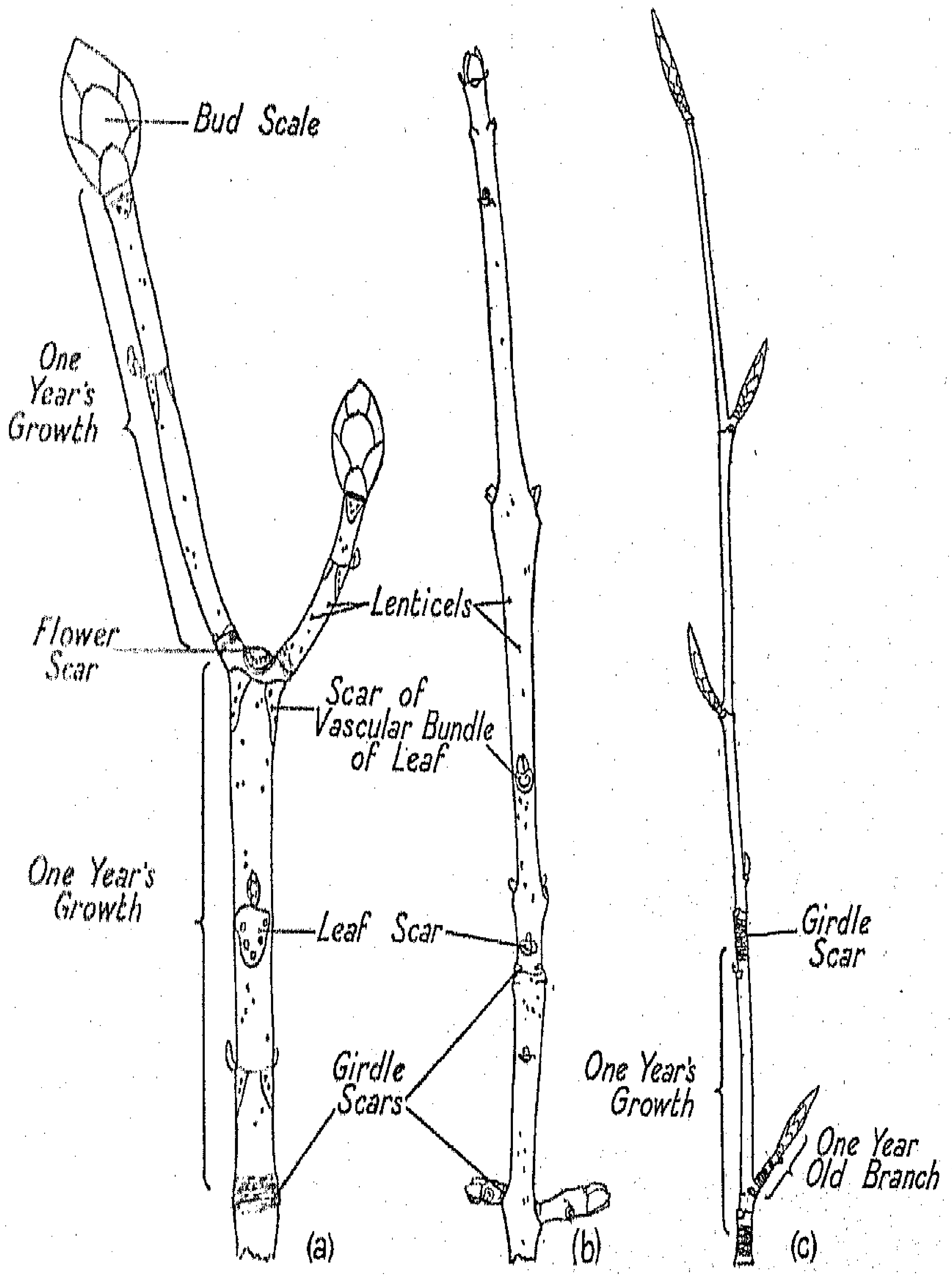

FIG. 142.—Winter twigs of (*a*) horse chestnut; (*b*) ash; (*c*) beech. (All ×½.)

If you examine a twig of a tree in the autumn you will find that every bud except the very end one is growing in the axil of a leaf. When the leaf finally drops off, a scar is left where its stalk was joined to the stem. This scar is easily seen on the winter twig (Fig. 142). There is one just below each bud except the end one. The leaf scars usually have a characteristic shape which you will soon learn to recognise. In the horse chestnut it is rather heart-shaped with a row of little dots arranged inside it. The country people imagine that it resembles a horseshoe and the dots are like the nail holes in the shoe. The dots

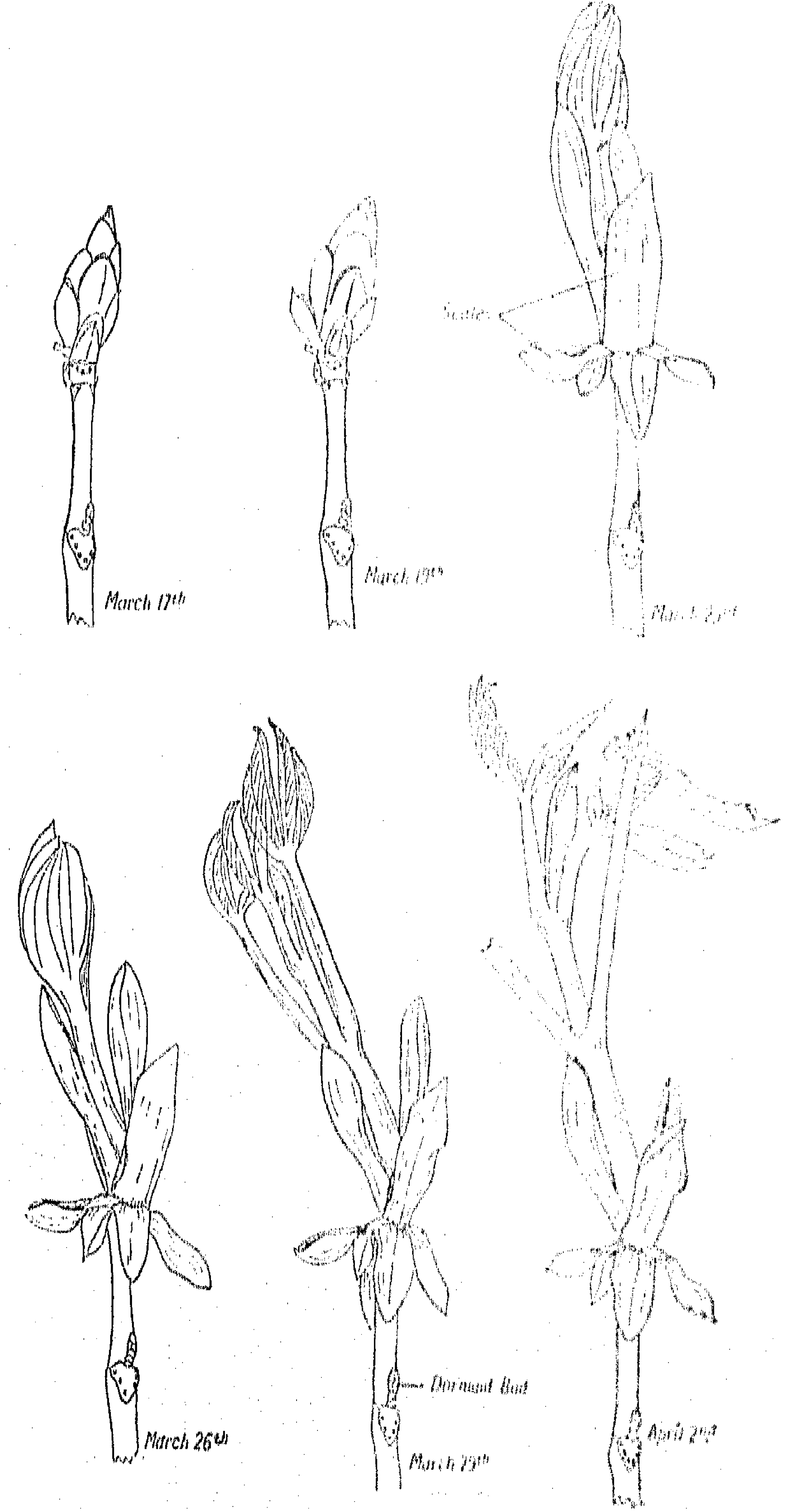

FIG. 143.—Stages in the opening of the winter bud of Horse Chestnut. The twig was kept indoors in water, and drawn on the dates shown. Note the small dormant bud which shows no signs of opening. (× ½).

are actually the blocked up ends of the pipes that carried water to the leaf when it was living, and the pipes were continuous with the veins of the leaf. In the leaf scars of some trees there is a continuous line instead of a row of dots.

Each spring, the winter buds grow into new twigs and usually a terminal bud carries on the growth of the twig that bears it (Fig. 143). If it does so year after year, a very regular form of tree will result, such as you get in a Christmas tree (Spruce Fir). Usually, however, after a few years' growth the terminal bud of a particular twig dies and further growth of that twig is carried on by a side bud, so that an irregular branching system results. This accounts for the sharp bends seen in the branches of oak and apple trees.

When a winter bud bursts in spring, the bud scales fall off and each of these leaves a little scar of its own. Where there are many bud scales, the result is a ring of scars going round the stem. Such a ring of scars is called a girdle scar. Since only winter buds can form girdle scars, it should be clear that the distance on the twig between two adjacent girdle scars will represent one year's growth (see Fig. 142).

It is possible to make an estimate of the age of a branch either by counting the number of girdle scars, or by cutting across it and counting the number of "annual rings" shown in the wood. These annual rings are formed because in spring when the tree is growing rapidly, a considerable amount of wood is made and this is rather open in texture. In late summer and autumn, when growth slows down, the wood is much closer in texture and is much less in amount, so the autumn ring is narrow in comparison with the spring ring. A complete annual ring consists of the broad band of spring wood and the narrow band of darker autumn wood. Fig. 144 is a drawing of a three-year-old lime twig which has been cut across, and it should make the method of counting clear to you. Should you come across the stump

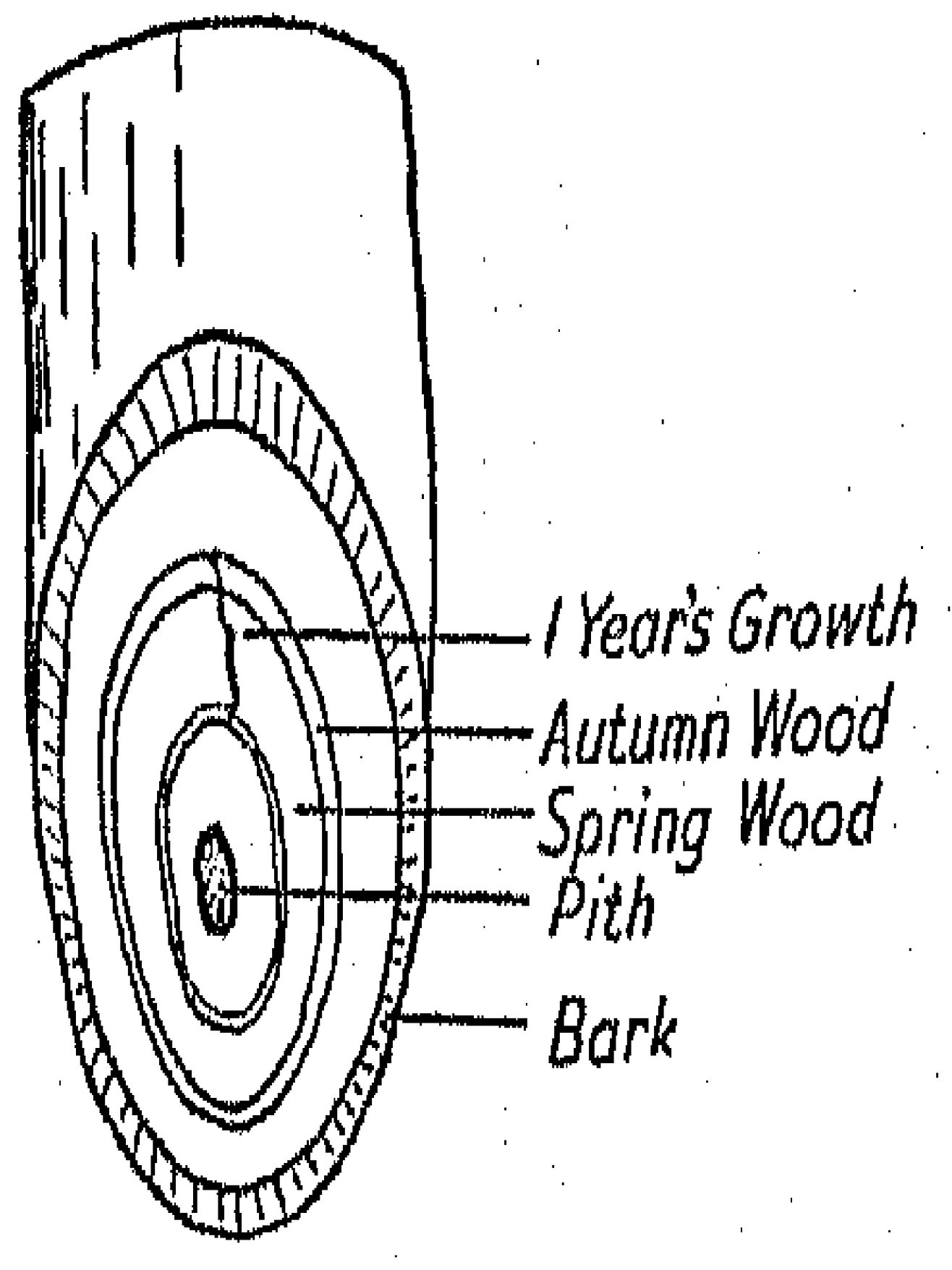

FIG. 144. — Annual rings. Oblique section through a three year old twig of lime, ×2.

of a tree that has been sawn down, you can, by counting the annual rings, discover the approximate age of the tree when it was felled.

The **Flowers** of trees are really quite like ordinary flowers. This is obviously true of such trees as the horse chestnut, apple, pear, plum, and cherry, but is less apparent for such trees as the oak, elm, and ash. Indeed I have met many people who were astonished to hear that these trees have flowers at all. There are two reasons for this ignorance. The first is that many trees are wind-pollinated and, as is usual in wind-pollinated flowers, they have no bright showy petals and so fail to be noticed by the human eye that is not specifically searching for them. The second is that many of our trees do not produce flowers until they are many years old and so are quite tall. It has been said that "man is an animal that can look up but seldom does", and this is fairly true. Very few people ever trouble to examine the higher branches of trees at all intently, and so they miss the rather inconspicuous flowers. The young trees, whose branches are nearer to the ground, do not have flowers.

As is fairly general among wind-pollinated flowers, the flowers of many trees open before the leaves appear. This is true of the ash, elm, and hazel. Hazel catkins are bunches of male flowers, the yellow colour being due to masses of pollen. Female flowers occur on the same tree as the male catkins, but they are quite different. They are produced by rather large buds, and when "open" show many scarlet threads protruding into the air. These threads are the stigmas (Fig. 145).

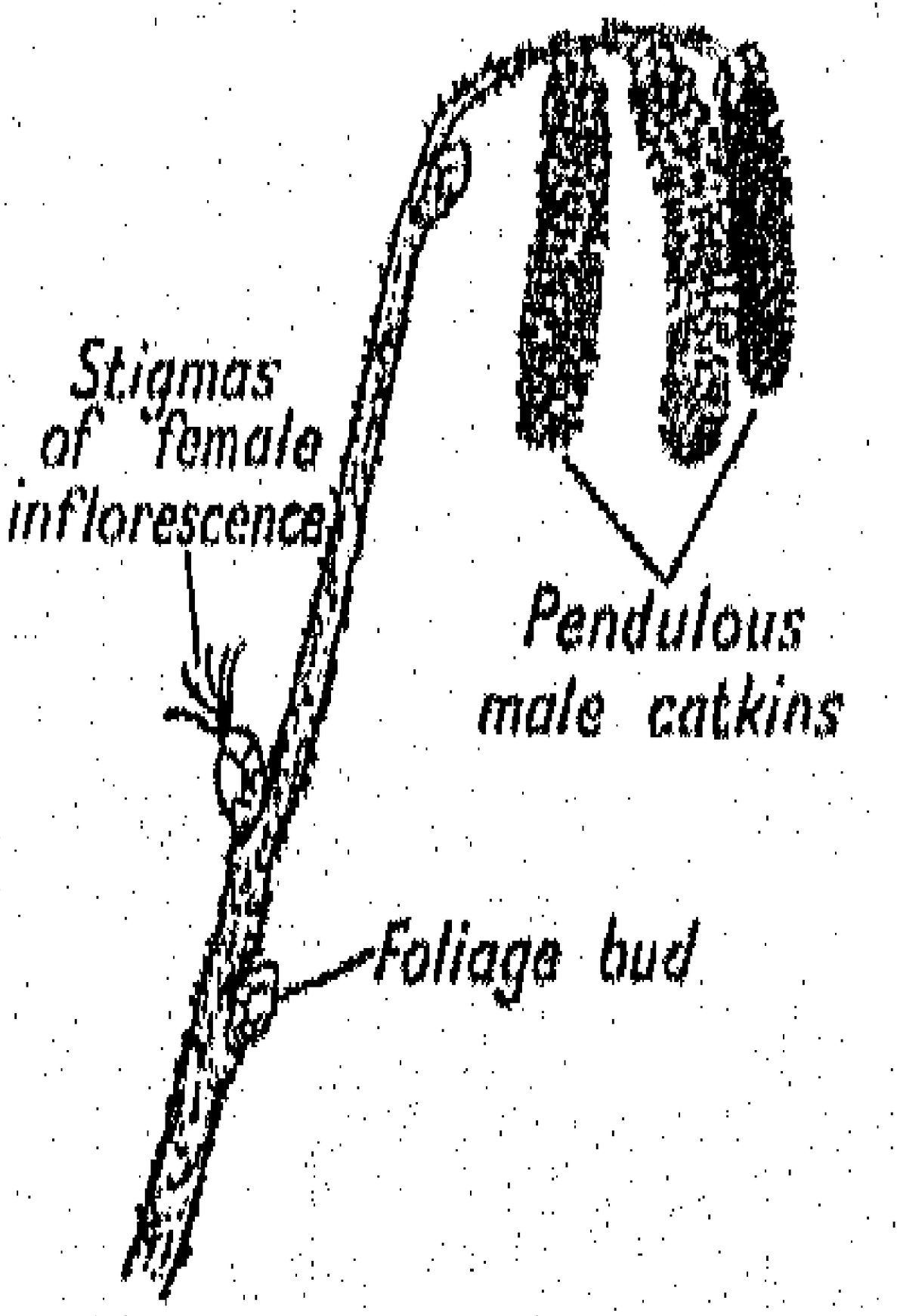

Fig. 145.—Twig of hazel, bearing male and female flowers, ×½.

Fig. 146 shows the structure of the flowers of the Wych Elm. The bunches of flowers are produced in April. The tree from which these were drawn grows at the foot of my garden. Under it are three bee hives and I noticed this year (1947) that the bees were very busy gathering the pollen from the elm flowers, although elms are wind-pollinated.

The oak tree has catkins of male and female flowers growing together on the same tree. They come out in May just after the leaves.

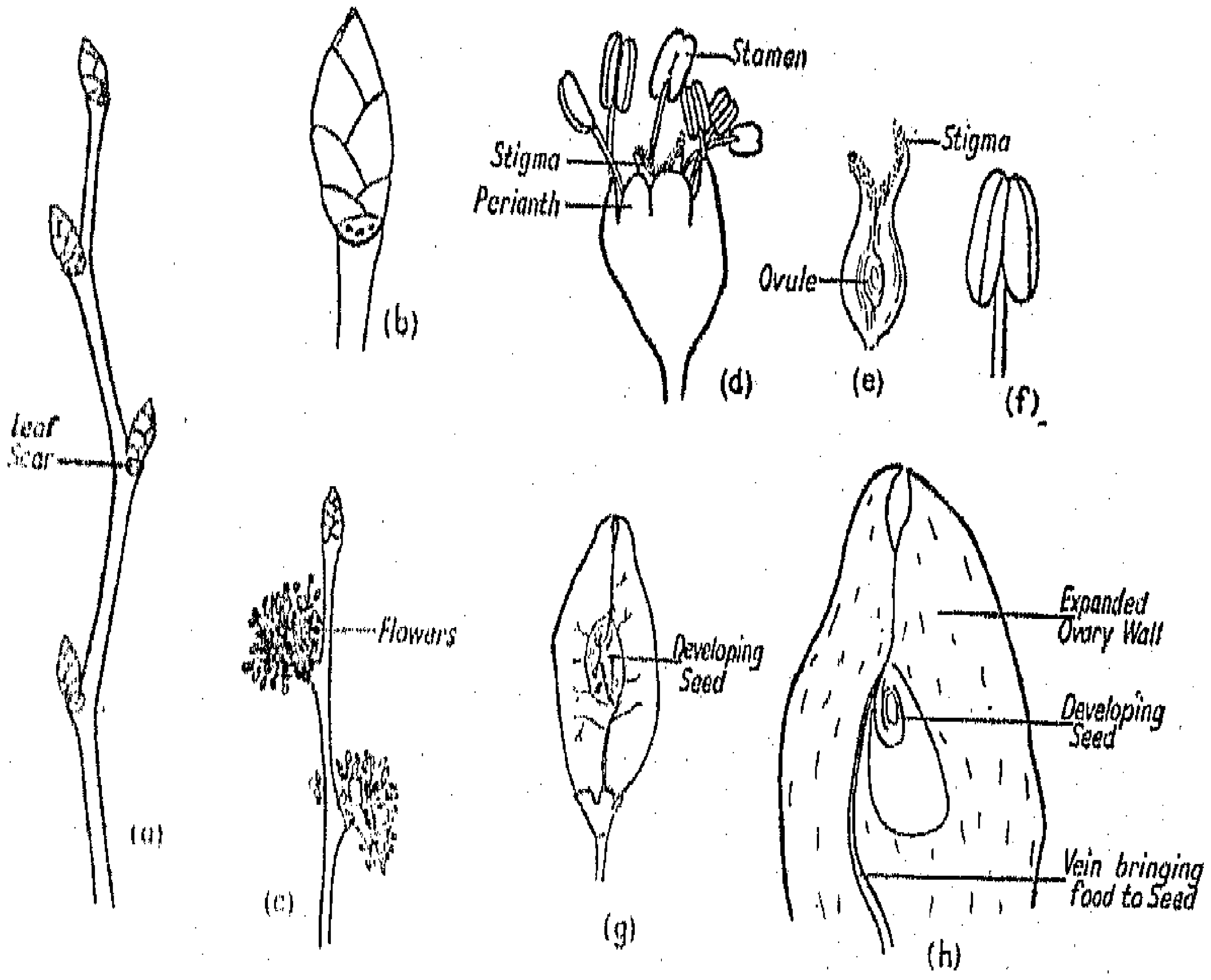

Fig. 146.—Wych Elm. (*a*) winter twig, bearing foliage buds; (*b*) single bud to show arrangement of bud scales; (*c*) twig bearing two groups of flowers; (*d*) a single flower; (*e*) isolated pistil; (*f*) stamen; (*g*) young fruit; (*h*) more highly magnified drawing of (*g*) with portion of ovary wall removed to show seed. (*a*) and (*c*) ×½, the others magnified to varying amounts.

Lime trees have flowers that do not blossom until early in July (Fig. 147). Each flower has five pale greenish-yellow petals. The flowers are fragrant and in favourable weather produce large quantities of nectar. Scent and nectar suggest that the tree is insect-pollinated and this is so, for the flowers are eagerly sought by bees.

Willows, also, have flowers that are pollinated by insects. There are two kinds of willow catkins, gold and green. The green ones are the female. The golden catkins produce the pollen and do not grow on the same trees as the green catkins,

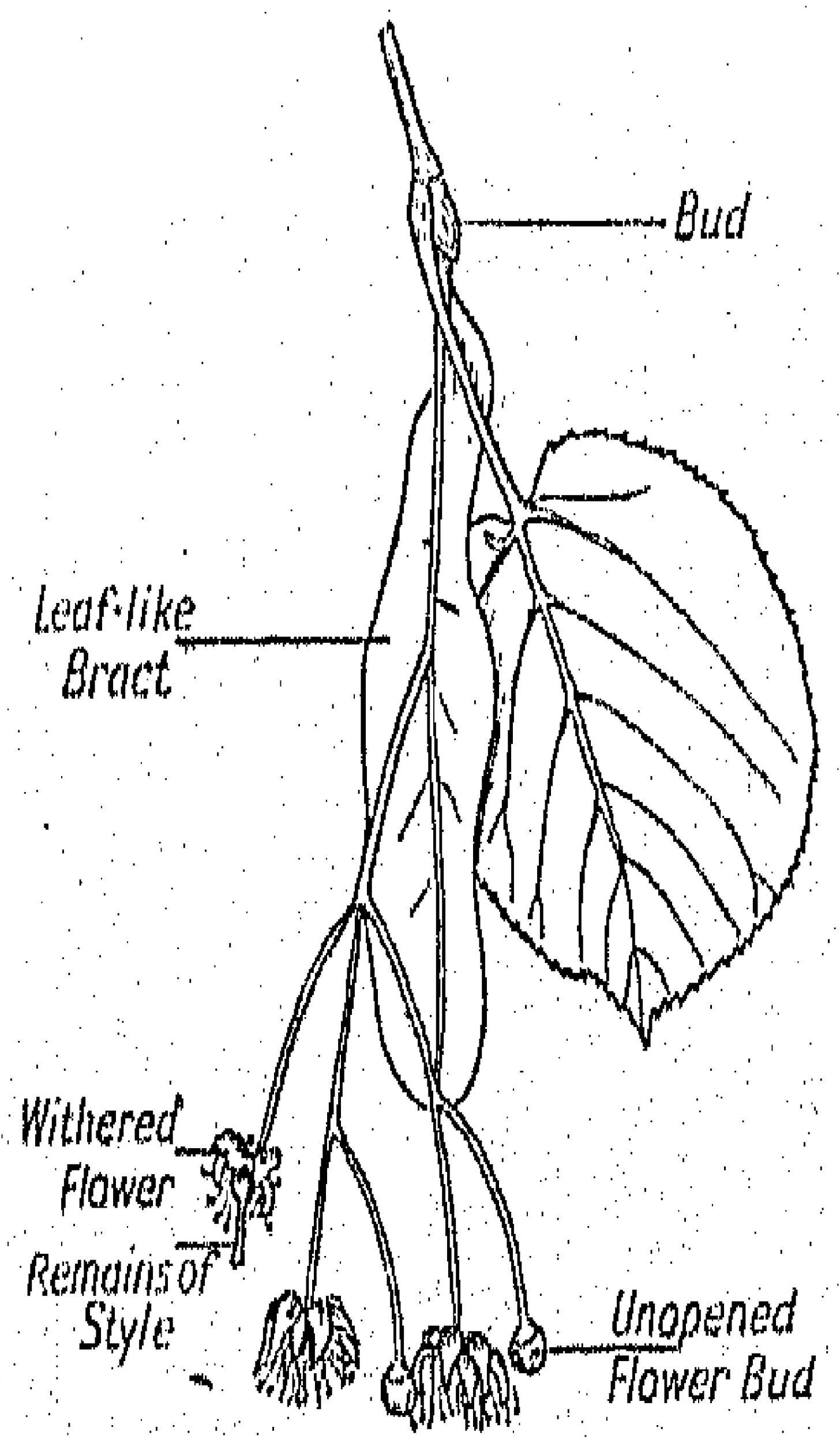

Fig. 147.—Lime flowers, ×½.

i.e., a particular tree produces either green or gold catkins but not both. These willow catkins are often sold in shops as they make such attractive spring decorations. Before they are fully out, both kinds are silvery.

Although you may not have noticed the flowers of many of these trees, it is quite likely that you are familiar with many of the fruits. Acorns of the oak, "conkers" of the horse chestnut, maple "boats", ash "keys", together with the gliding fruits of the sycamore, are common enough objects.

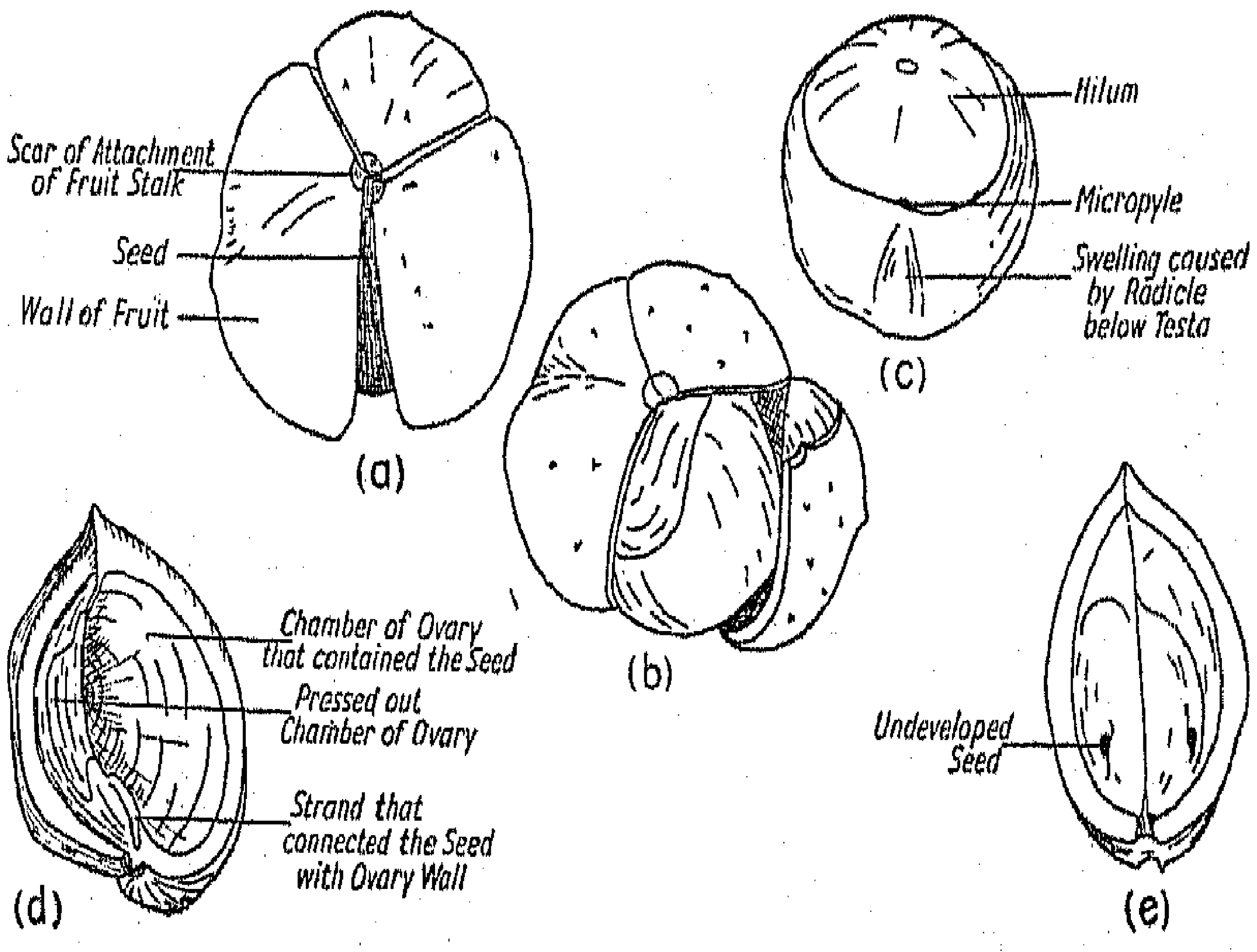
Scar of Attachment of Fruit Stalk
Seed
Wall of Fruit
(a)
Hilum
Micropyle
Swelling caused by Radicle below Testa
(c)
(b)
Chamber of Ovary that contained the Seed
Pressed out Chamber of Ovary
Strand that connected the Seed with Ovary Wall
(d)
Undeveloped Seed
(e)

FIG. 148.—Horse Chestnut fruit and seeds. (*a*) fruit capsule beginning to split; (*b*) the same, with one valve partially removed; (*c*) a single seed or "conker"; (*d*) and (*e*) two of the valves. (All × ½.)

The "conker" is actually a seed (see p. 221); the real fruit, i.e., seed plus the ovary in which it developed, is the green spiky structure shown in Fig. 148*a*. The round scar on every "conker" is the hilum where the "conker" was fixed to the ovary, and through which it received its nourishment while it was developing.

Acorns are fruit, i.e., each acorn is a ripe ovary with a single seed inside it. Quite a number of our English trees have fruits that are provided with some sort of wing to allow them to be blown a long way from the parent tree. This is desirable as it would not be satisfactory for all the seeds from a tree to grow up around their parent—there would not be room and they would crowd one another. These gliding fruits are made by part or all of the ovary wall being drawn out into a thin plate. When the fruit is ripe, the plate becomes dry and light and causes the fruit to fall slowly even in still air. If there is any wind, these seeds may travel considerable distances. I have found fruit of birch trees on top of a church tower a long way from the nearest birch tree. Some of these winged fruits are shown in Figs. 125 and 126.

Conifers

There is a group of trees we call "conifers", and they differ in some ways from other trees. To the conifer group belong the pines, spruces (Xmas trees), yews, cedars, cypresses, and many other evergreen trees commonly grown in cemeteries, parks, and ornamental gardens.

Here are some features that will enable you to recognise a conifer:

(1) The leaves are narrow or needle-like, sometimes very small. Usually there is no leaf stalk, but yew leaves do have a short one.

(2) The seeds are not produced inside a closed ovary, but are borne upon the outer surfaces of scales which are usually woody. In most conifers these scales are grouped together to form "cones" (Fig. 152), of which the familiar fir cones are a good example. The woody cones tend to stay on the tree for some time after the seeds are set free. Again the yew tree is exceptional, for its fruit consists of a single seed set in a fleshy cup which becomes bright red when ripe.

(3) In all English conifers, except larches, the tree remains clothed with leaves throughout the winter, although every year some of the older leaves are shed. (Because of preservative resins they contain, the leaves of conifers rot but slowly, and the ground beneath such trees usually has only scant vegetation. In parks you will see that grass rarely grows underneath conifers, and for this reason gardeners frequently dig the ground under these trees.

The Scotch Pine is probably the most suitable tree to study as an example of a conifer. But as this tree is not to be seen everywhere, particularly in towns, I shall tell you something of the CYPRESS TREE, which is often planted in gardens and almost invariably in parks and ornamental gardens.

The commonest cypress (Lawson's Cypress) grows into a handsome pyramid-shaped tree which may reach forty feet in height. The twigs tend to grow all in one plane, so that a piece of a branch broken off will have a flat appearance. The leaves are very small, about $\frac{1}{10}$ inch long, and grow tightly pressed to the stem, which is completely hidden by them and consequently has a scaly appearance. Close inspection will show that the leaves are arranged in opposite pairs. The leaves on the top and under surface of the stem are wider than those at the sides (Fig. 149), so that the twig itself is flattened. On the older branches the leaves will have been shed, but the scars where they were attached can usually be seen. The leaves are rather glossy and those on top of the twig are a dark green, though the ones on the undersurface are much lighter green, especially near the tips of the twigs. The colour tends to become darker in older leaves, partly because of the dirt which falls on to them from the air.

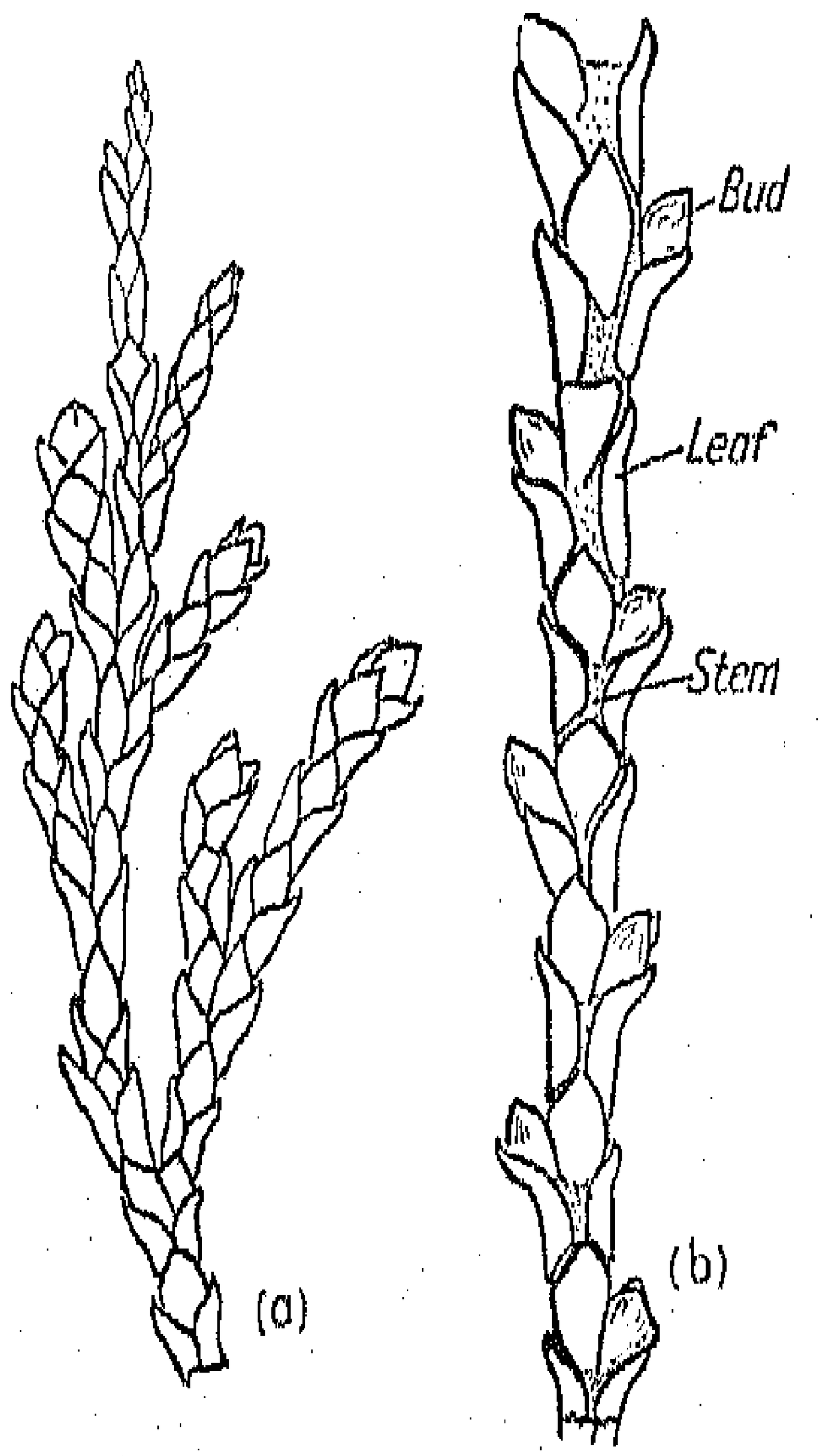

FIG. 149.—Lawson's Cypress. (*a*) young twigs at the end of a branch; (*b*) portion of an older branch. (Both ×2.)

The trunk is covered with corky bark. This is often raised into roughened rings, about $\frac{1}{4}$ inch wide, which encircle the trunk.

Close inspection will usually reveal the presence of old cones on the twigs. These are about the size of a pea and are made of dark brown corky material. Each cone has a central pillar to which are attached eight scales which stand out from it more or less at right angles. From in between these scales the seeds have escaped, and frequently a few seeds may be discovered still wedged between the scales.

To find female cones in their youngest stages you must examine the tree in May. The female cones are found at the tips of the branches and consist of a cluster of tiny leaves (Fig. 150), each leaf bearing two tiny ovules on its upper surface. Hence the seeds are quite open to the air, not protected inside a closed ovary chamber as in flowering plants (see p. 19). The young cones soon grow into structures about the size and shape of a large pea. Each consists now of eight scales tightly pressed together by their edges to form a solid sphere. Each scale has a small hook-like projection in the middle of its outer surface (Fig. 150). The scales are greenish with a suggestion of purple. If you take such a cone to pieces, you will be able to see the developing seeds lying between the scales, as indeed you can in the female cones of any other conifer. Because of their large size the cones of Scotch Pine make good material to study.

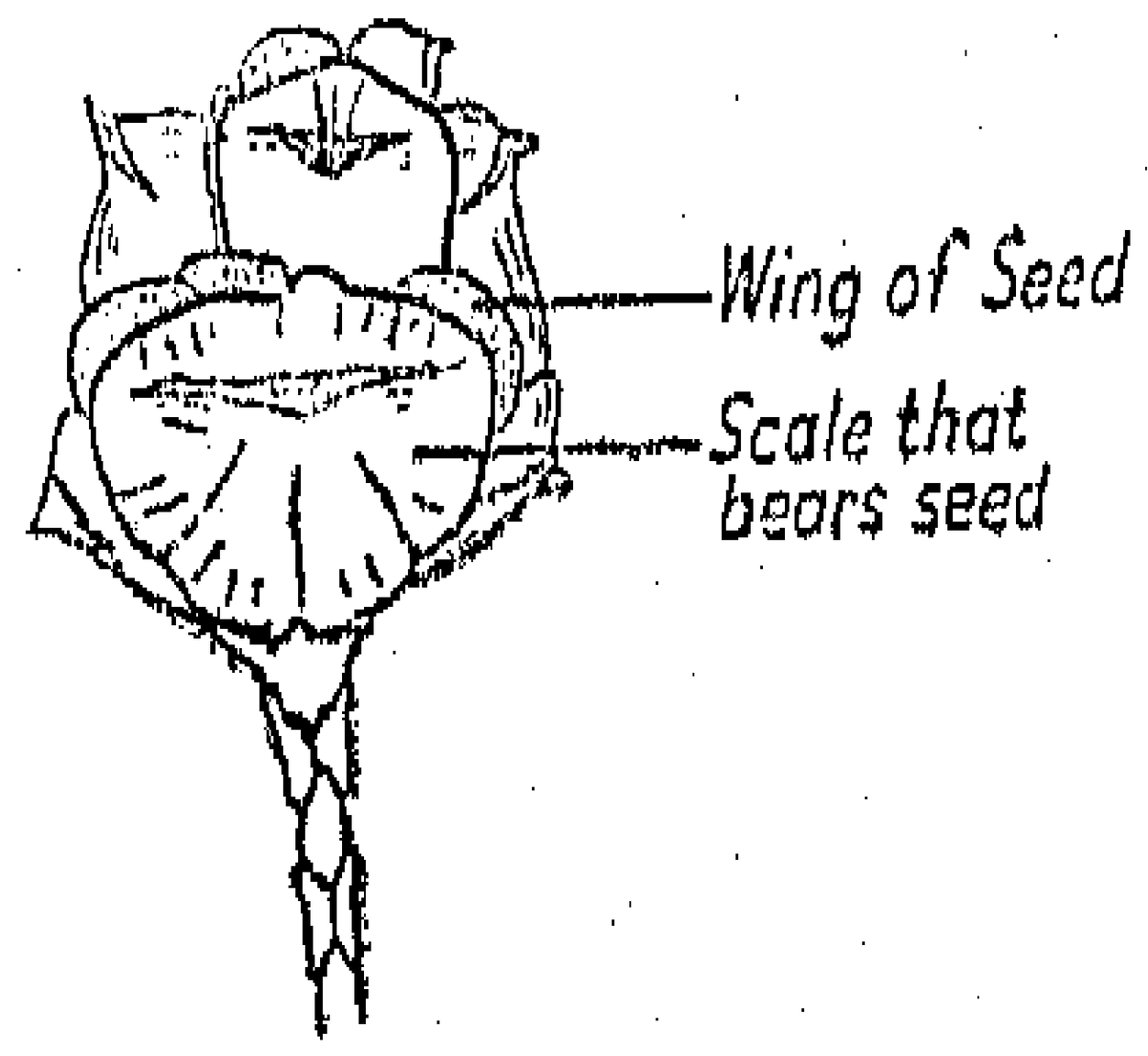

FIG. 150.—Mature female cone of Lawson's Cypress, ×2.

The male cones of the cypress produce pollen. They are found at the tips of the branches in the same way as the female cones. The male cones are cylindrical in shape and marked with patches of crimson, so that they are quite easy to see. Each cone consists of several scales which bear pollen chambers on their under sides. The structure will be better understood if you refer to Fig. 151.

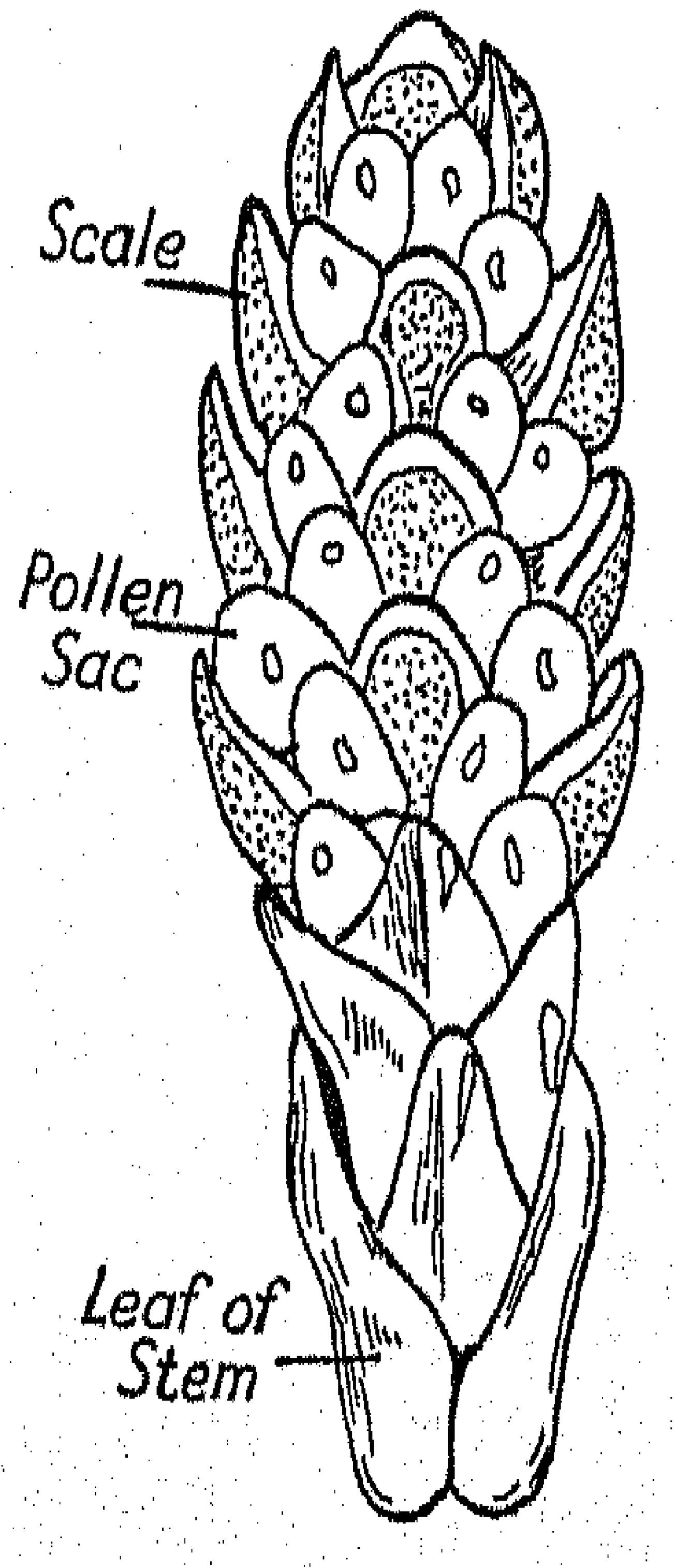

FIG. 151.—Male cone of Lawson's Cypress (considerably enlarged). (Redrawn from the *Botanical Magazine*.)

All conifers are wind-pollinated. The pollen is blown from the male cones to the female ones and later the ovules are fertilised. After this the ovules develop into seeds. The seeds of most conifers are each provided with a delicate wing which enables them to travel long distances when blown by the wind

(Fig. 152 and Fig. 133*a*). From most ripe cones you should be able to obtain a few seeds, especially if you split down the tough scales with a penknife. The seeds are usually dark brown in colour.

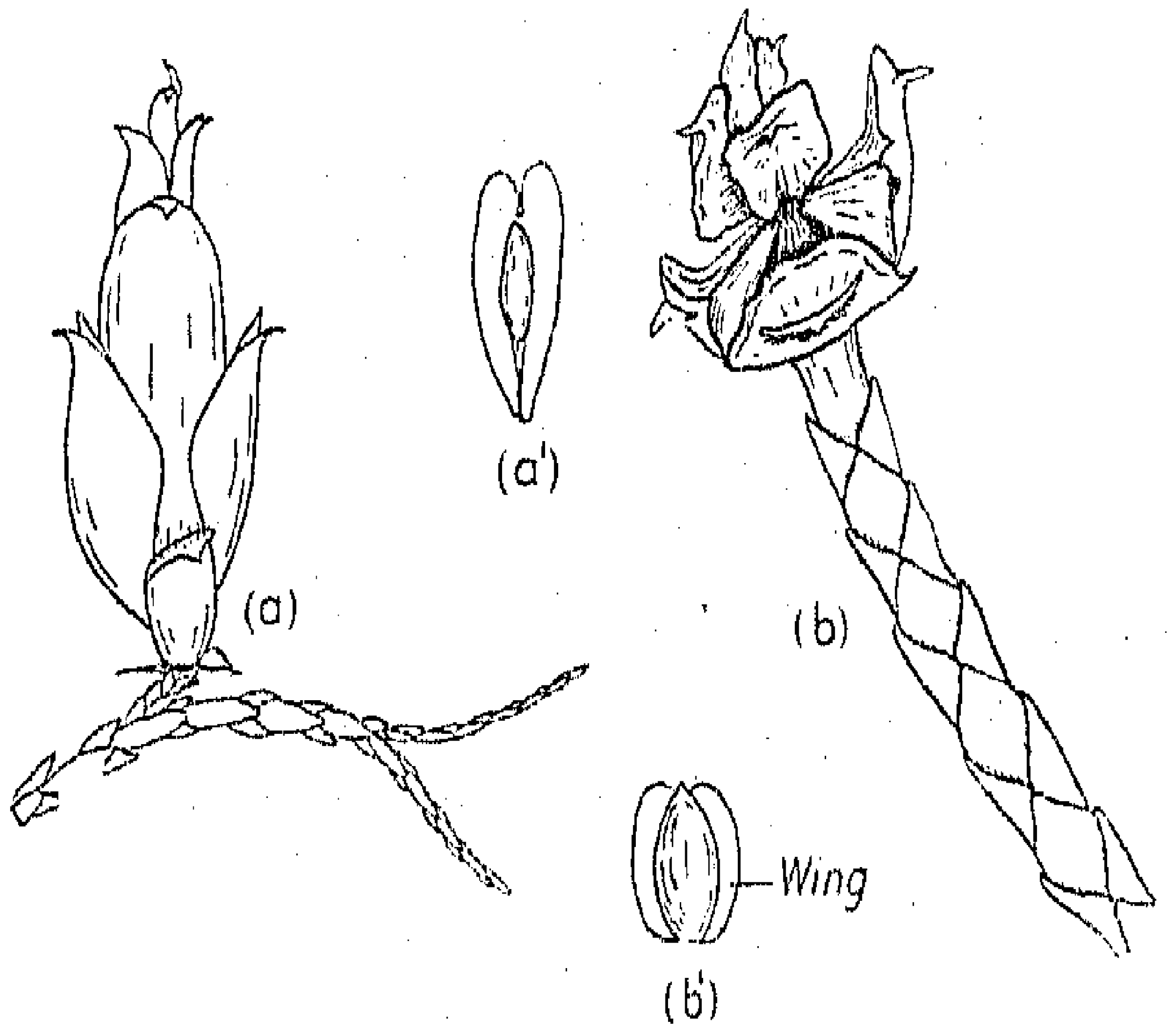

FIG. 152.—(*a*) mature female cone of *Thuya*; (*a'*) seed of *Thuya*; (*b*) empty female cone of Lawson's Cypress; (*b'*) seed of Lawson's Cypress. (All ×3.)

There is only one other conifer you may mistake for a cypress. This is the *Thuya* or Arbor Vitæ which is frequently grown in parks and gardens. The general appearance of the tree is similar to that of a Lawson's Cypress, but the bark on the trunk has no rings on it. Moreover, the leaves give off a pleasant smell when crushed between the fingers, whereas Lawson's Cypress leaves emit no smell when bruised.* The most distinctive difference, however, is provided by the female cones. These are nearly ¾ inch long and rather spindle-shaped. The colour of old ones is reddish-brown. The scales are rather oblong in shape and have a small hook at the tip, whereas those of Lawson's Cypress have hooks in the middle of the outer face. Instead of standing at right angles to the axis of the cone the scales of *Thuya* are clustered round it, somewhat like the petals in a rose bud (Fig. 152 *a*). As late as Christmas, seeds will be found in these cones.

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* Certain other cypresses are fragrant.

CHAPTER TWENTY-SIX

Life in Fresh Water

THE conditions of life in fresh water are in many ways easier and more uniform than the conditions of life on land. One of the main problems that has to be solved by land organisms is how to avoid the danger of desiccation through excessive water loss. Many animals (e.g., mammals, birds, reptiles, and most insects) have developed a general surface covering that is more or less watertight, and the majority of land plants have a cuticle that is impermeable to water vapour, at least when the cuticle is dry. Such forms do lose water to some extent, e.g., through the lungs in mammals and through the stomates of the leaves in plants, but it is lost in an amount that may usually be easily replaced. That the skins of the animals cited above do retain water has been convincingly demonstrated by hanging, side by side in a dry atmosphere, a skinned lizard and a similar unskinned lizard. The former lost weight rapidly due to the evaporation of moisture, while the unskinned animal lost weight only slowly.

On the other hand many land animals, e.g., slugs, earthworms, and frogs, readily lose water vapour through their skins to a dry atmosphere, and this fact considerably restricts their activities. Most people will have noticed the abundance of slugs after rain, and remarked on their apparent absence during a dry spell. At such times they may be found in an inactive state under large stones or dead logs, or buried in the soil, in all of which situations a relatively damp atmosphere is to be found.

The only aquatic organisms that need fear desiccation are those inhabiting shallow ponds or streams that are liable to dry up during summer. In such forms it is not unusual to find some drought-resisting stage in the life history as, for instance, the resting spores of some algæ. The aquatic snail *Planorbis spirorbis* (the Button Ram's Horn) is capable of closing its shell with an epiphragm in the event of its pond drying up.

Similarly, many animals are capable of burying themselves in the mud, and remaining alive, though in a dormant condition. Some aquatic plants, such as duckweeds and water starwort, are capable of living for some time, in shaded situations, on the mud of dried ponds.

That the danger from drought may be a real one was forcibly impressed on me during the exceptionally dry summer of 1947, when I observed the drying up of a small trout stream in Wales. When the stream first ceased to run, all the fishes congregated in the deeper pools that still contained water. Later, as the water in these also dried up, the trout were to be found under the large stones where the gravel still retained some moisture, and small live fishes were there for a day or so after the stream had become quite dry, though many fishes lay dead on the bed of the stream and provided a rare feast for seagulls that had flown in from the coast. Small eels were present for some days longer.

Water

Water is a rather dense fluid and affords considerable mechanical support to organisms living in it. Consequently aquatic creatures do not require a strong skeleton for purposes of support, though a skeleton may be required for purposes of defence or offence. This ability to dispense with a supporting skeleton is clearly seen in aquatic plants, which usually lack the hard supporting tissues present in the larger land plants. Plants such as water starwort, or Canadian pond weed, look most attractive when growing submerged, and their weak stems are capable of supporting the various organs under water. If these plants are removed from water they collapse at once into shapeless masses, their weight in air being far too great to be supported by the stems. It is well known that the larger whales frequently break their backs if they become stranded and thus deprived of the support afforded by the water. Many of the free swimming aquatic animals have a density very close to that of water, and consequently are able to maintain themselves in any desired position in the water with relatively little expenditure of energy. The bony fishes are provided with a gas-filled "swim bladder" lying along the dorsal side of the body cavity. The fish can increase the volume of the swim bladder by secreting more gas into it, or decrease the volume by absorbing gas, and in this way can adjust its buoyancy so that it is enabled to remain suspended practically motionless in the water. Small pike, and rudd, are frequently to be seen in this manner near the surface of large ponds and lakes. Some caddis-worms construct quite heavy cases that on land they could drag only with difficulty. In water, however, they can manage them easily enough, though some forms that construct particularly heavy cases attach small pieces of wood to give greater buoyancy. The fruits of water lilies (Fig. 153) float at the surface, and, when the capsules rot, seeds may be liberated at considerable distances from the parent plants.

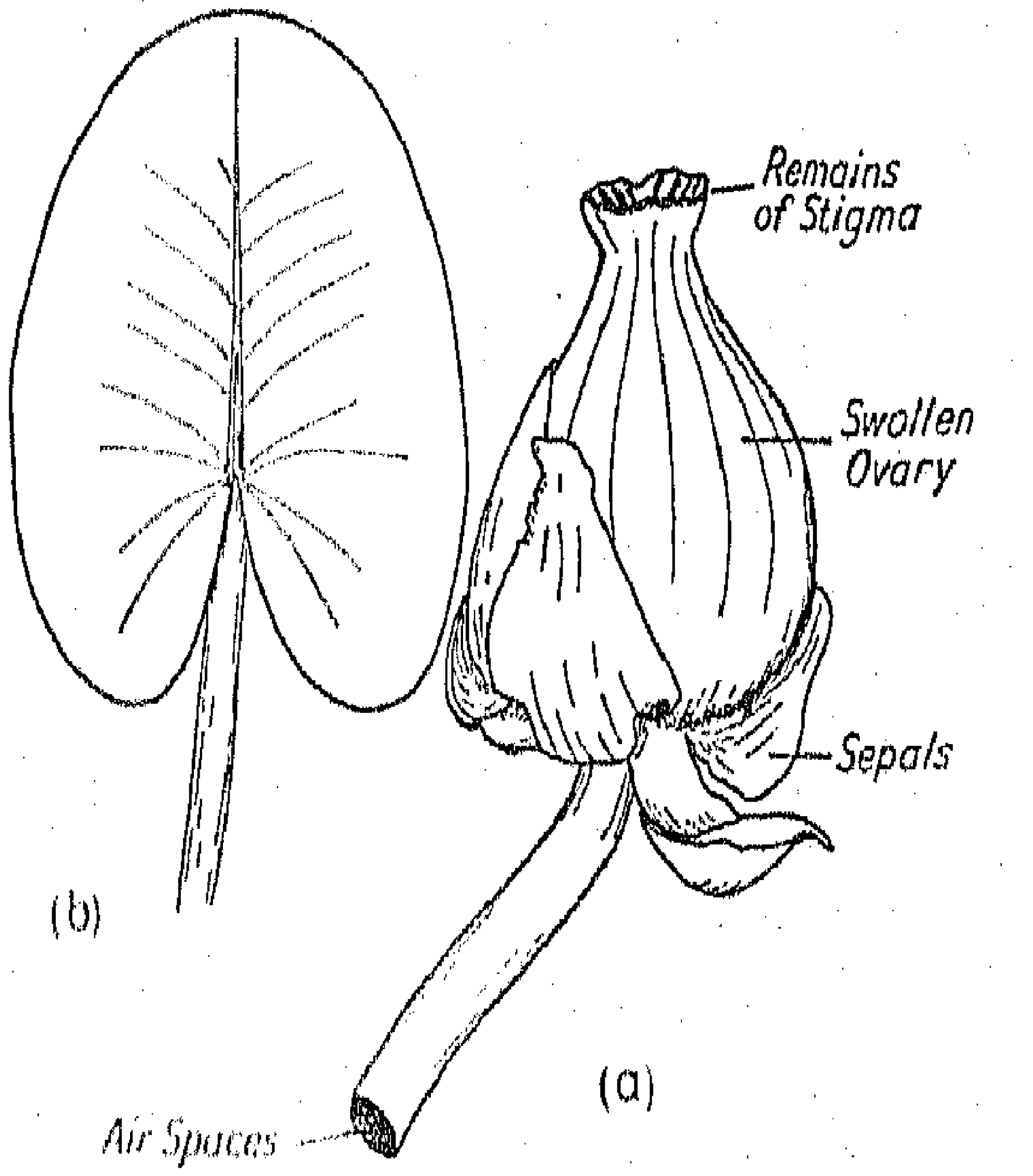


FIG. 153.—Yellow Water Lily (*Nuphar luteum*). (*a*) fruit and portion of peduncle; (*b*) leaf. [(*a*) $\times \frac{3}{4}$; (*b*) $\times \frac{1}{4}$.]

The fact that water has a high surface tension, i.e., behaves *as if* it had a tough elastic membrane at its surface, is of some importance to aquatic life. It enables the sea to produce waves in shallow water that "break" with considerable force, making it difficult for inter-tidal animals and plants to maintain themselves. It is not unreasonable to assume that it is to meet this force that limpets have evolved their thick conical shells, and that the holdfast of the common brown seaweed Bladder Wrack is so well developed (Fig. 154).

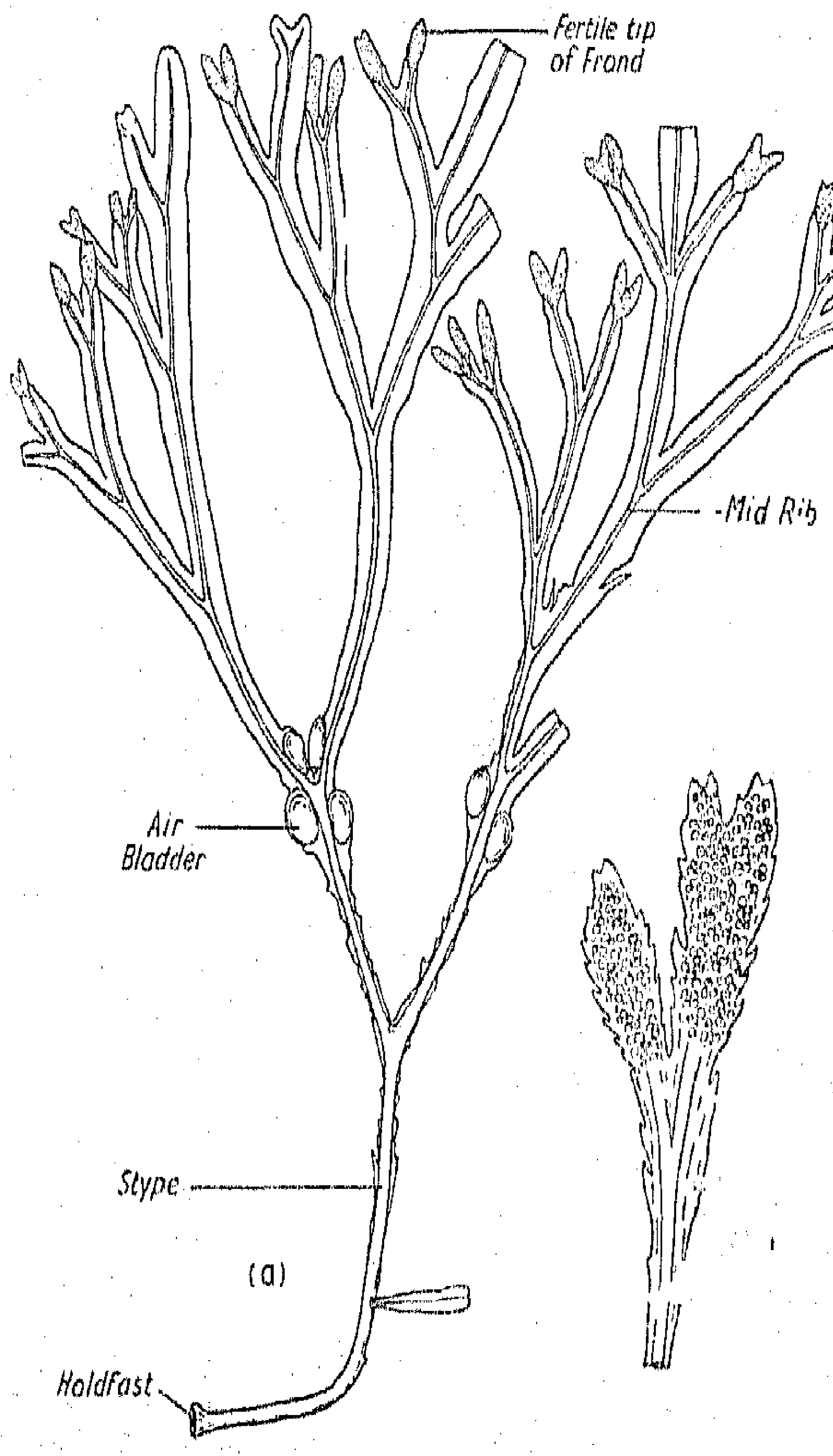


FIG. 154.—(*a*) small plant of Bladder Wrack (*Fucus vesiculosus*): (*b*) fertile tip of frond of the related Serrated Wrack (*F. serratus*). (Both ×½.)

The surface film of fresh water provides a habitat on which several forms of life can dwell, notably the pond skaters, whirli-gig beetles, and the tiny black springtail, *Podura*. Snails frequently travel along the under surface, and many other aquatic animals are capable of hanging suspended, supported only by the forces of surface tension. This is true of mosquito larvæ and pupæ, water scorpions, water boatmen, and aquatic crane fly larvæ. Such forms usually have hairs or flaps of tissue at the region which lies in the surface film, so as to increase the area on which the surface tension can act.

On the other hand, many insects become wetted by the surface film, and the force of adhesion of water is so great compared with their strength that the insects are trapped and quite unable to escape. They remain struggling impotently until they either drown or are eaten by fishes or other predators.

Respiration

One of the major problems presented by living in fresh water is that of obtaining oxygen. Oxygen is fairly soluble in water, but, in common with other gases, is less soluble in warm water than in cold. The vital processes of organisms living in water, however, go on more rapidly when the water is warm —bacterial action and the respiration of animals, for instance— and it follows that their need for oxygen may be greatest when the supply is least, as during nights towards the end of summer when the water is warm and when the green plants cannot produce oxygen by photosynthesis.

Many aquatic organisms obtain their oxygen directly from the water by the physical process of diffusion, by which the dissolved oxygen present in the water passes through some permeable region of the organism's body. In aquatic plants the whole of the body surface is presumably permeable to dissolved oxygen, and because plants have a relatively diffuse shape, which implies a large surface area in proportion to the body volume, this simple diffusion is in general satisfactory, at least for small plants. Most of the larger aquatic plants have internal spaces in their leaves or stems in which oxygen made by photosynthesis during the daytime is stored. This oxygen is available for the plants' use at night. These inter-cellular air spaces can be well seen in the stems and leaf petioles of water lilies.

Small aquatic animals may obtain sufficient oxygen by diffusion through the general body surface. However, the larger animals have a relatively compact shape and the ratio of surface area to body volume is low. Hence, simple diffusion of dissolved oxygen through the general body surface is likely to be insufficient to satisfy the needs of the animals, at least during periods when the concentration of dissolved oxygen is low. To meet this difficulty, the larger forms develop special respiratory surfaces that possess a relatively large surface area. Such surfaces are called gills, and usually consist of thin projections of the body surface that are richly supplied either with blood vessels,

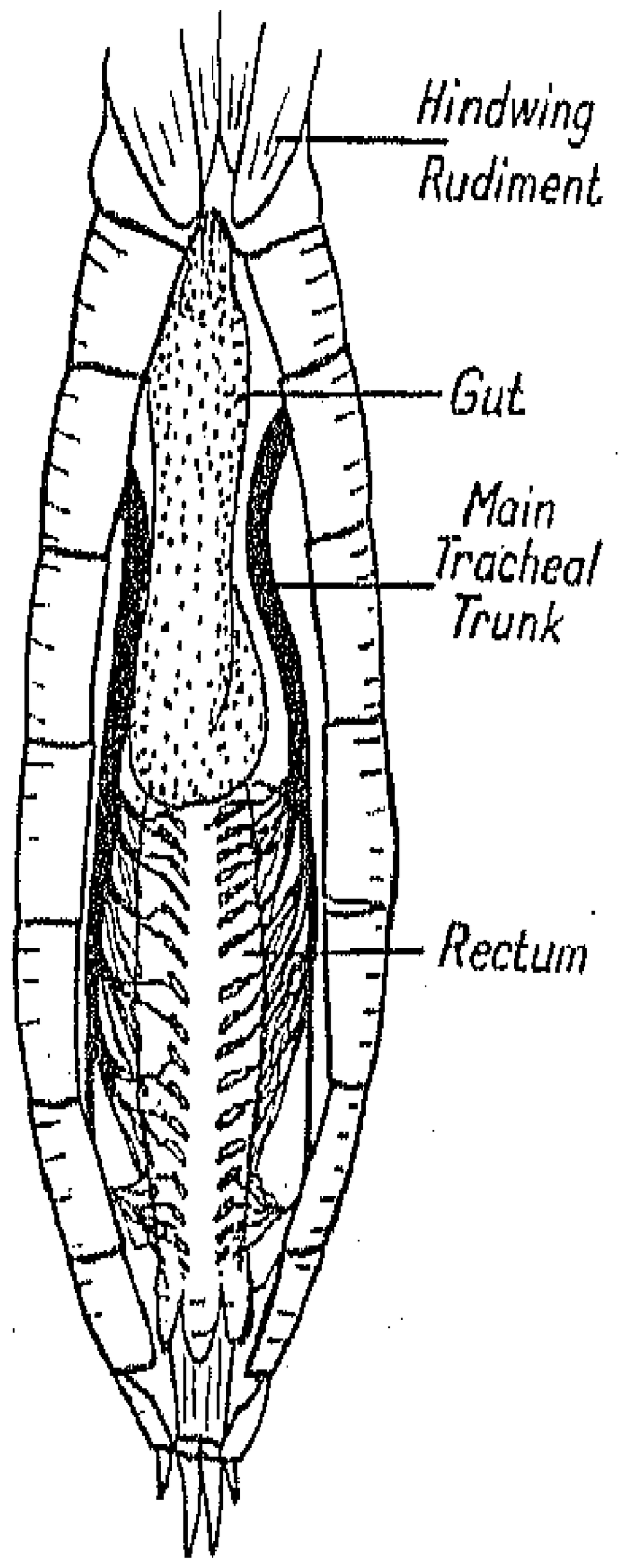


Fig. 155. — The rectal gills of a dragon-fly (*Aeschna*) nymph. The abdomen of the nymph has been opened from the dorsal surface to expose the rectum with its rich supply of tracheæ. (× 2).

or, in insects, with tracheæ. The gills of fishes have already been described (p. 61).

Damsel fly nymphs (p. 178) have three thin broad plates which function as gills, situated at the posterior end of the abdomen, while the dragon-fly nymphs have a series of elaborate gills inside the rectum (Fig. 155). These rectal gills may easily be seen if the rectum of a large dragon-fly nymph is opened by making a dorsal cut with scissors.

Gills are present in other aquatic insects that breathe dissolved oxygen. Examples are the abdominal gills of many may-fly nymphs, and the thread-like gills on the abdominal segments of the larger caddis-worms (Fig. 156). Each caddis-worm dwells inside a tube, and as the oxygen dissolved in the water present in the space bounded by the insect's body wall and the inner wall of the tube is soon exhausted, a constant flow of water through the tube must be maintained. This is effected by rhythmical movements of the caddis-worm's body. The caddis-worm obtains a firm hold on its case by means of two hooks present at the posterior end of the abdomen, and by three fleshy protuberances present on the first abdominal segment, which press firmly against the wall of the tube.

Many aquatic creatures ascend to the surface to obtain atmospheric oxygen. We have already seen (p. 77) that this is so in the group of snails (the pulmonates) that inhabit still water which, on occasion, is likely to have a low oxygen concentration. The gill breathing snails (the operculates) are usually to be found only in running water or well aerated still water. In addition, these latter forms are small, and consequently have a large surface area compared with their body volume, a factor that always facilitates successful respiration through the skin.

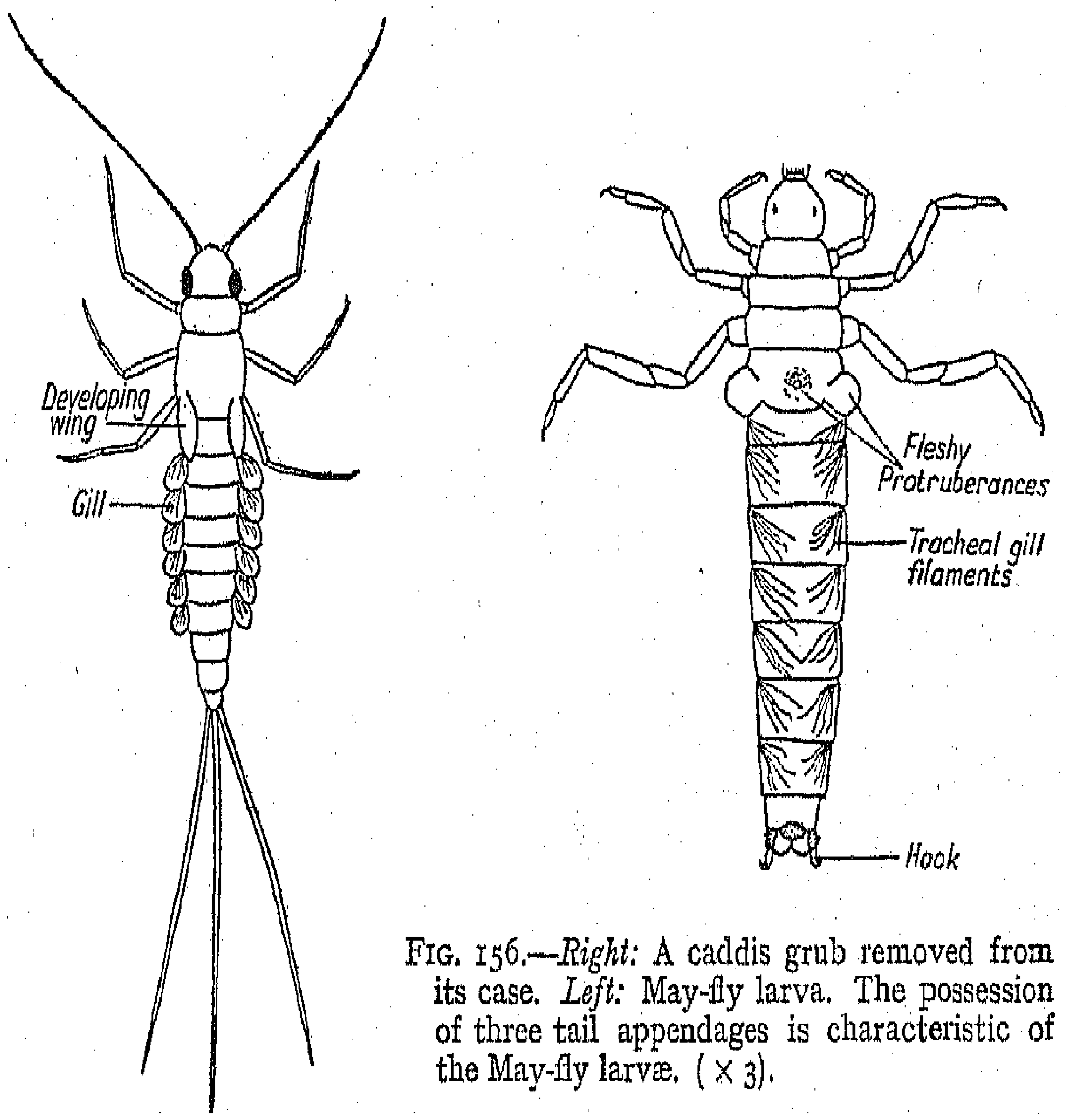


Fig. 156.—*Right:* A caddis grub removed from its case. *Left:* May-fly larva. The possession of three tail appendages is characteristic of the May-fly larvæ. (× 3).

Water scorpions, mosquito larvæ, and the rat-tailed larvæ of *Eristalis* (Fig. 157), take in atmospheric oxygen through their siphons, which are in communication with the tracheal systems. The Lesser Water Boatmen have two large spiracles on the sides of the thorax, and the thorax of these creatures pushes through the surface film when they come to the surface to breathe. A thin layer of air is retained in this region when they dive, and has the appearance, under water, of a band of silver.

The functional spiracles of the Greater Water Boatmen (Fig. 158) are also on the thorax, but in these creatures a layer of air, retained by long hairs, envelops the whole of the abdomen as well as the spiracles. When a Greater Water

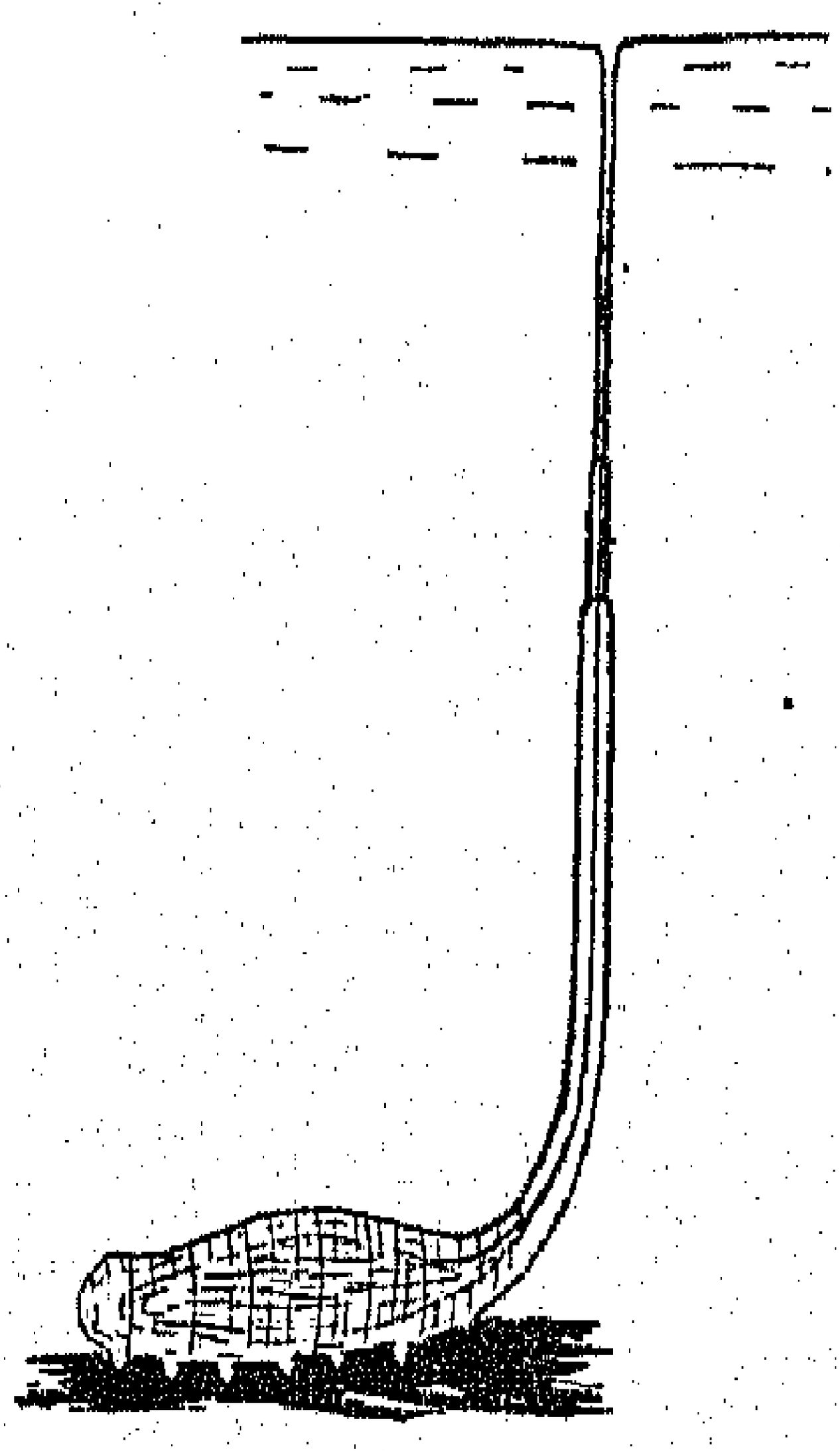


Fig. 157. — The Rat-tailed Maggot of the Drone Fly (*Eristalis*) using its telescopic siphon to obtain air from the surface, × 2.

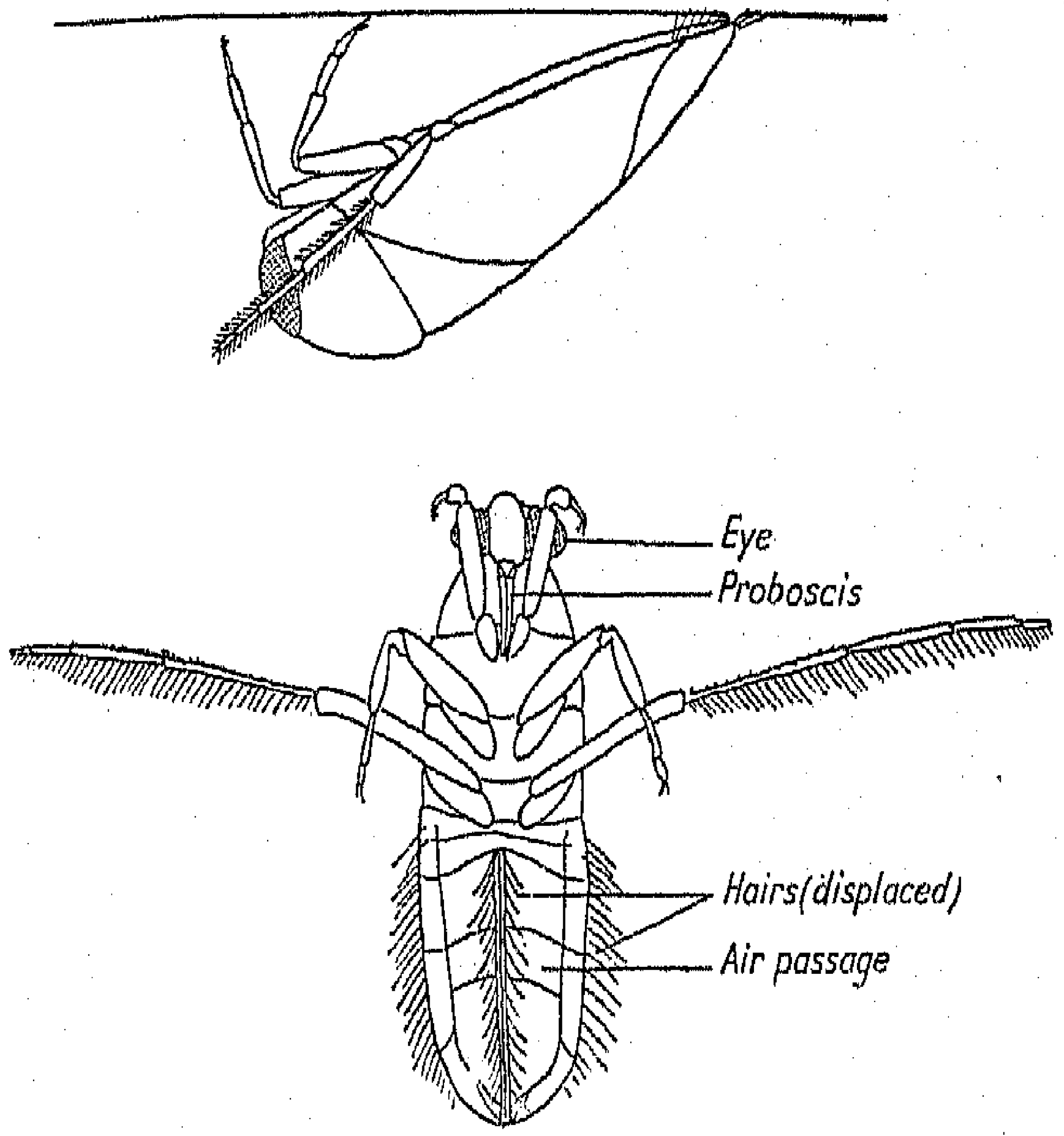


FIG. 158.—The Greater Water Boatman (*Notonecta*). *Above:* breathing at the surface. *Below:* ventral view of *Notonecta* with the hairs displaced to reveal the abdominal air passage, ×2.

Boatman comes to the surface for a fresh supply of air it is the tail that is protruded, and fresh oxygen diffuses at this region into the air film round the body, and so ultimately makes its way to the spiracles. It is the film of air trapped in the "air passages" that gives the silvery appearance to the ventral surface of a submerged *Notonecta*. On the dorsal side the film is hidden by the wings.

The entry of water into the spiracles of aquatic insects is prevented by the presence of waxed hairs guarding the apertures. Water does not wet them, and consequently, because of its surface tension, cannot enter. The action may be visualised by imagining a fine glass tube placed in mercury—the mercury will not enter the lumen of the tube.

The Great Diving Beetle, *Dytiscus*, takes atmospheric air into a space under the elytra by coming rapidly to the surface and protruding its tail. The tracheal system communicates with the air space through spiracles situated on the dorsal abdominal surface. Other beetles obtain oxygen in a rather similar manner, but also retain a gas bubble at the tip of the abdomen. The bubble is carried by the beetle as it travels through the water and is believed to serve not merely as an additional supply of air, but also as a gill. It is thought that as the oxygen concentration of the gas trapped below the elytra is diminished, so too, since the two are in communication, the oxygen concentration inside the bubble diminishes. When the oxygen concentration inside the bubble falls below the oxygen concentration of the outside water, the dissolved oxygen of the surrounding water will begin to pass into the bubble by diffusion. It is probable that the air films carried by *Notonecta*, and other animals, function in the same manner.

Green plants, in the presence of carbon dioxide and light, produce oxygen as one of the end products of photosynthesis. The equation for this action is

Light energy + carbon dioxide + water = a sugar + oxygen

Some of the oxygen is used at once by the plant for its own respiration, but this amount is generally only a small fraction of the total quantity produced. In many aquatic plants (e.g., the algæ) the surplus oxygen simply diffuses into the water, but in the higher plants, as already stated, it frequently passes into air spaces in the plant tissues (Fig. 153). Even so, much dissolves in the surrounding water, or, under particularly good conditions, may be evolved as bubbles which, though not pure oxygen, are sufficiently rich in this gas to relight a glowing splint. The gas may be collected experimentally by the apparatus shown in Fig. 159. *Elodea* is a suitable plant to employ, but it is best, if the experiment is to be performed, previously to enrich the water with carbon dioxide by bubbling the gas through for several minutes, or by adding a pinch of sodium bicarbonate to it.

From the foregoing it will be obvious that the water around green plants will, in still water, tend to be rich in dissolved oxygen and this probably is of considerable importance for the many animals that lay their eggs either on or in the tissues of aquatic plants. Dragonflies and water scorpions lay their eggs actually embedded, newts and many caddis-flies attach their eggs to the sur-

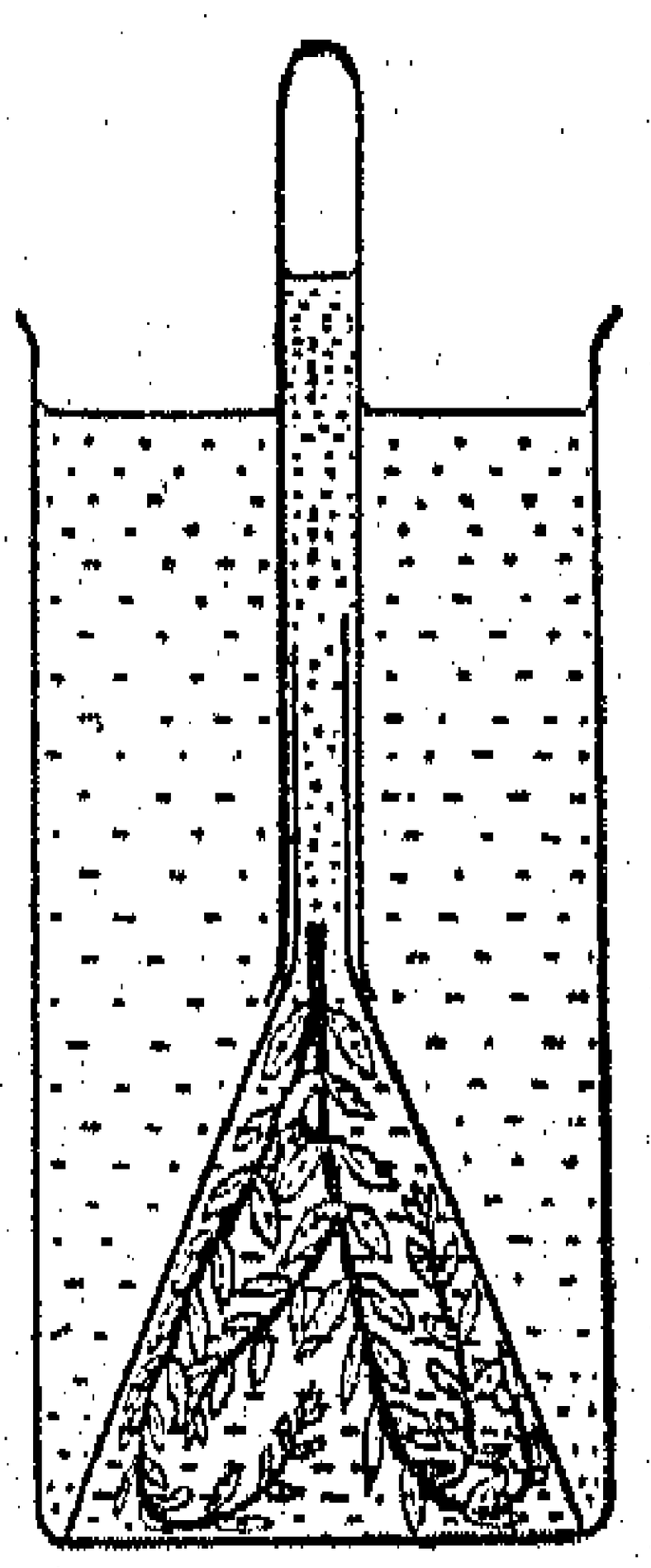


FIG. 159.—Apparatus for collecting the gas evolved by water plants during photosynthesis.

faces, and toads twine the egg strands amongst the plants. The behaviour of newly-hatched tadpoles, which attach themselves by their cement glands to aquatic plants, ensures that they will be in well oxygenated water, and the presence of many microscopic animals on strands of certain algæ may also be thus partially explained.

The Balance of Pond Life

A permanent pond is, in some senses, a closed community, and remains relatively stable over a period of years. In water, as on land, the primary food producers are the green plants which, by their photosynthetic activity, assimilate carbon from carbon dioxide and build it into carbohydrates. The carbohydrates can be further synthesised into proteins by combination with certain elements, notably nitrogen, phosphorus, potassium, and sulphur, obtained in the form of mineral salts. Ultimately, it is the available quantity of these salts that determines the amount of plant material that can be produced by a particular stretch of water. After a period of intense plant growth, the concentrations of some of the necessary salts may fall to zero because the original supplies have by now all been assimilated by the plants. Thus it happens in ponds and closed lakes, and even in the sea, that after the first flush of growth vegetation increases only very slowly.

All animals ultimately depend on green plants for their food, because the animals either eat the plants directly, as do herbivorous animals, or eat other animals which eat the green plants (Fig. 160). It may happen that larger carnivores eat smaller carnivores, as, for instance, a pike eating a perch; but as the smaller carnivores eat herbivores, it is obvious that the food of all carnivores ultimately depends on green plants. It follows, also, that the total animal life a pond can sustain over a period of time will depend on the amount of vegetation the pond can support, and, in turn, that depends on the quantity of minerals available.

Under natural conditions the mineral content of a pond is restored in one of three ways.

(1) By the decay of the droppings of herbivorous and carnivorous animals. Such decay is brought about by the activities of bacteria and fungi, and goes on most readily

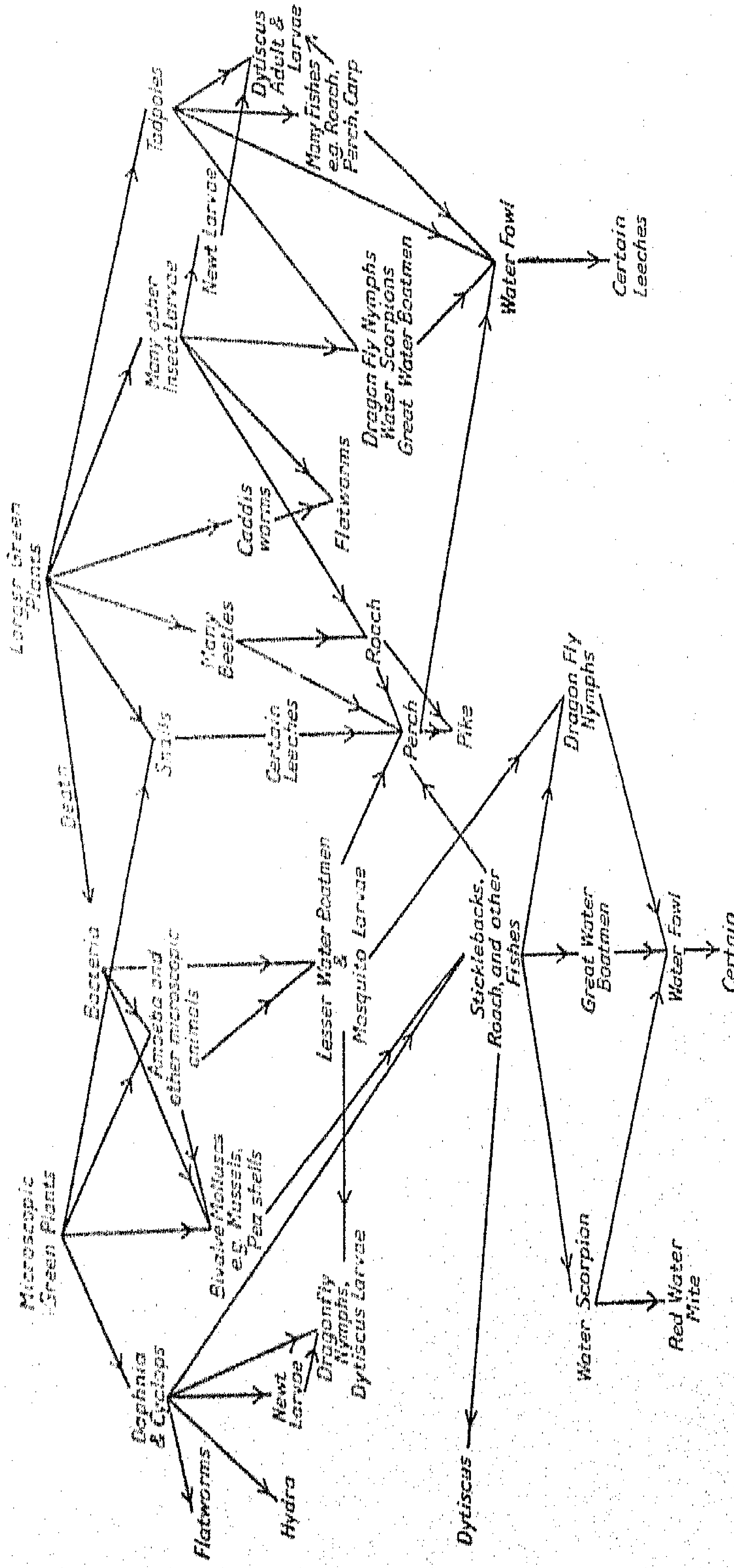


FIG. 160.—Some of the food relationships of pond organisms.

in well oxygenated waters when the temperature is reasonably high.

(2) By the decay of the dead bodies of animals. This takes place as for (1), but most dead bodies are eaten by scavengers and so would be returned as minerals under (1).

(3) By the decay of dead plant material. The majority of the plants do not die until autumn. During the winter, in shallow ponds, the water temperature is low and organic decomposition consequently proceeds slowly. Hence, the main release of minerals from this source will not take place until the warmer days of the following spring and early summer.

In streams, especially those flowing through rich agricultural land, mineral salts are constantly being acquired through the influx of drainage water. The salts are ultimately carried out to sea, except where the streams flow into closed lakes. In such cases the lakes act as traps for minerals, and will be able to support considerable animal and plant populations.

A loss of mineral salts to a pond occurs in the bodies of creatures that pass their young stages in the water but leave it as adults. Frogs, for example, lay their eggs in ponds, the tadpoles hatch and feed voraciously for about twelve weeks, and then leave the ponds, carrying away in their body substance considerable quantities of minerals. As they do not, in general, return to the ponds to die, this represents a serious mineral loss to the pond, comparable to the loss to a field when a crop, say of potatoes, is taken from it. A similar circumstance occurs with many other animals—caddis-flies, dragonflies, may-flies, and mosquitoes, to name but four. Other mineral losses may occur through the activities of water hens, herons, and other birds that feed on aquatic organisms, though some minerals may be returned as faeces.

The pond will regain minerals in drainage water and in the form of plant material which falls into the pond and gradually decays, and a balanced state between mineral loss and mineral gain probably exists in most long established ponds. However, the total plant life in any stretch of natural water can be increased by adding artificial "fertilisers". Increased plant life means increased animal life, and so it is not surprising to find

that "fertilising" stretches of water has been considered as a method of increasing the fish yield, especially of trout and sea fishes. Experiments conducted during the war on an arm of the sea (Loch Craiglin, Argyllshire) were quite successful in increasing the fish yield, though it did not prove economic, in this loch, to harvest the fish. On the other hand, water intended for use by water supply undertakings should contain as little plant life as possible, since this clogs the filters and is expensive to remove. Hence, in reservoirs the aim is to keep down the quantity of mineral salts, and one way of doing this is to remove a crop of fish at intervals.

Maintaining an Aquarium

Aquaria are often used to study certain aspects of aquatic life, and a few words on setting up an aquarium may not be out of place.

Almost any receptacle will serve as an aquarium; I use jam-pots and pickle jars freely, but the need for ensuring an adequate supply of oxygen has constantly to be borne in mind. If green plants are not present, oxygen can enter the water only through the free water surface where it is in contact with the air, and if a choice of aquaria is possible, those that will provide a large area of free water surface should be selected (Fig. 161). For example, a short squat honey jar should be chosen in preference to a tall pattern. The crucial point, however, is the ratio between the extent of water surface exposed to the air and the volume of the water. If this ratio is high, the water will be better aerated than if it is low. Consequently, the golden rule with either tall or narrow containers is not to place too much water in them. I find that jam-pots half filled will serve well enough for most creatures.

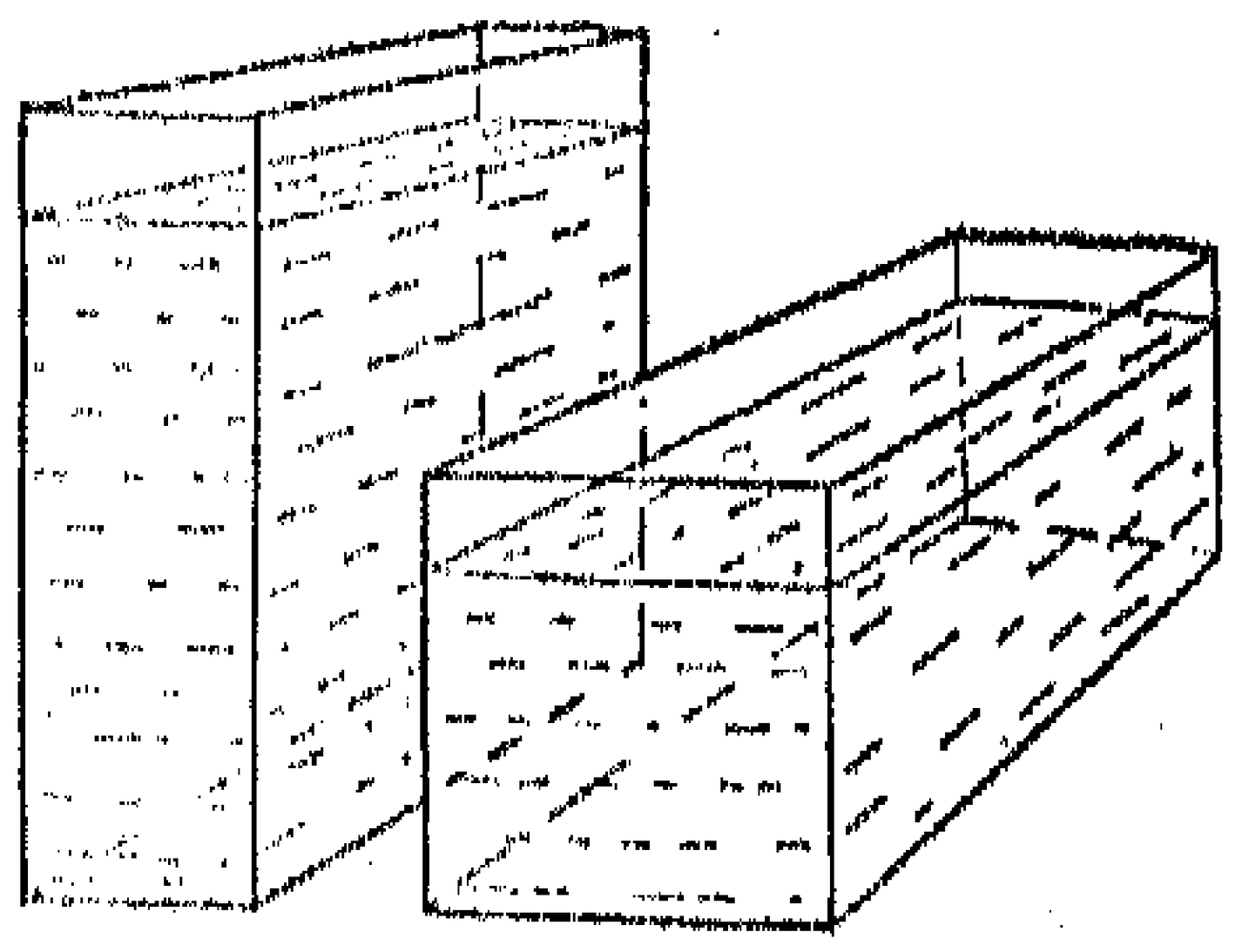


FIG. 161.—Aquarium shapes. The tall narrow shape shown on the left is undesirable, as it has too little free water surface. The shape shown on the right is much more suitable.

I do not use mechanical aerators myself, but find that, when necessary, a useful method of aerating the larger tanks is to invert a dry plant pot on the bottom. This will continue for about a day to liberate tiny bubbles of air as the air in the porous earthenware is gradually replaced by water. When the pot is thoroughly soaked it must be replaced by another dry one. It is useful to keep four or five pots handy, so that a constant supply of dry ones is available.

In setting up a new aquarium, even though it is only a jam-pot, try to obtain pond or river water, as tap water may contain chemicals injurious to aquatic life. Rain water will serve quite well, but pond water is likely to contain numerous microscopic organisms that will play a useful part in the economy of the aquarium. To cover the bottom of the aquarium, I recommend pond mud or fine gravel from a river. Silver sand is frequently used, but this lacks the plant nutrients and the micro-organisms present in pond mud.

Aquatic plants should always be added to an aquarium, not only because of their value as oxygenators, but also because of the shade they provide for animals. Duckweeds (*Lemna minor* and *L. trisulca* are most satisfactory) will live on the surface, hornwort grows floating freely, while *Elodea* and water milfoil grow either rooted to the bottom or floating freely. If it is desired to root plants in the mud this may be achieved by attaching the lower ends of their stalks to pieces of lead foil, which are then buried. Without the lead, the plants tend to float to the surface after a day or so, especially if moving animals are present.

A usual mistake is to keep too many animals together in an aquarium. In a restricted volume of water the available oxygen may be used rapidly, especially if fishes are present. Also, the herbivores have little chance of escaping from the carnivores, and considerable discrimination is needed in choosing the inhabitants if wholesale slaughter is to be avoided. For purposes of study it is best to maintain separate small aquaria (jam-pots will serve) for such carnivores as *Dytiscus*, water scorpions, *Notonecta*, and dragonfly larvæ, and to feed them individually. Most of these carnivores will eat blow-fly maggots or small lively worms, or failing either of these, small pieces of raw meat. Carnivores may usually be induced to seize a piece of meat if it is dragged slowly past them by means of a piece of cotton. Uneaten meat must be removed after half a day or so, or the water will become foul. This applies to all excess food, though worms and maggots will live for several days in

well oxygenated water, and as long as they are alive will not cause the water to become tainted. *Cyclops* and *Daphnia* are excellent food for many creatures. Cultures may easily be maintained in water containing decaying leaves, provided that they are shielded from direct sunlight.

Though light is necessary for the well being of the plants in an aquarium, direct sunlight falling on an aquarium for any length of time is injurious to the animals, and should not be permitted. Indoors, aquaria may advantageously be placed near windows facing north or west. Out of doors, any shaded place will serve, though cats may be a nuisance, and precautions should be taken, if necessary, to prevent them upsetting the smaller jars. Aquaria must be protected from frost, for if the water freezes, the container will almost certainly be smashed.

CHAPTER TWENTY-SEVEN

How Plants and Animals Replace Themselves

ONE of the important facts about living things is that individuals do not live for ever. Either they are killed by accident or by other living things, or else sooner or later they die in the normal course of nature. But before they die most living things make some sort of provision to replace themselves. This process, we have seen, is called reproduction, and it is one of the most important of the activities of living things. Without it, all life on the earth would rapidly come to an end, and the possession of the power to reproduce is one of the main differences between living and non-living things.

Asexual Reproduction

The simplest kind of reproduction is that in which the plant or animal splits off from itself a part which is capable, in time, of growing by itself into a new plant or animal like the parent. This type of reproduction is called asexual, and it is most common in plants, though it does occur in some animals.

One of the best plants for the study of asexual reproduction is the Duckweed (p. 35). Shake up a little garden soil in a jam-pot of water to provide food for the plants. Then put in it a single duckweed plant, transferring it with a brush or twig so as not to damage it. Draw its outline carefully and then leave it in a well lit place for a few days. Draw it again and you should find some change on comparing the two sketches (Fig. 162). Draw it two or three more times at intervals of a few days, and by the end of a fortnight or so you will probably have several small duckweed plants floating in your pot. Your series of drawings will show you how these have arisen from the parent plant. You will see that new duckweed fronds are budded out from the sides of the parent frond, from which they differ only in being smaller and a brighter green in colour. After making this experiment it will be obvious to you why it is that, in summer, ponds and slow streams often become completely covered with duckweed. Quite a number of small water plants, and some animals, reproduce themselves in this way, but we shall not consider them further here.

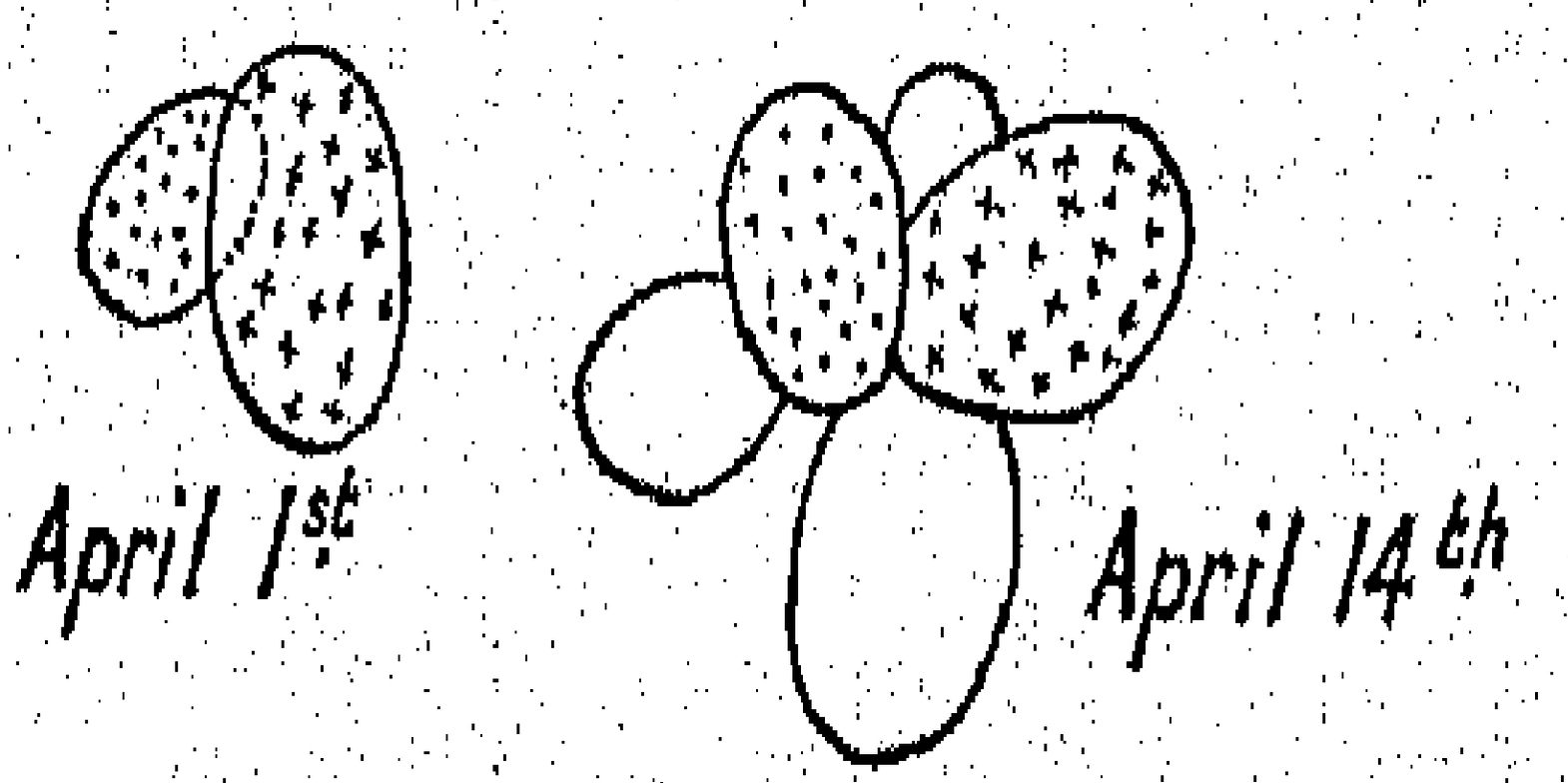


FIG. 162. — Reproduction in the lesser Duckweed. (× 20).

Land plants rarely split off parts in quite such a simple fashion, but, if pieces become broken off from the main plant they will frequently make roots and grow into new plants. This is the reason why gardeners can sometimes make new plants by taking cuttings. The ordinary **GERANIUM** is a plant which gives good results. Cut off from the plant a piece about 6 inches long, making the cut just below a node (i.e., a place on the stem where a leaf is growing), and remove all leaves except two or three at the top. I always leave the cutting exposed to the air for half a day so that a layer of varnish is made by the plant over the cut surface; but this may not be necessary. Place the cutting about 3 inches deep in a plant pot nearly full of earth. It is usually considered best to place the cutting against the side of the pot and have the stalk actually embedded in silver sand, to ensure an adequate supply of oxygen. In less than two months you will find that the cutting has developed roots and is beginning to grow. It is best to do several at once to avoid possible disappointment, and you must remember to keep the soil watered if it is indoors.

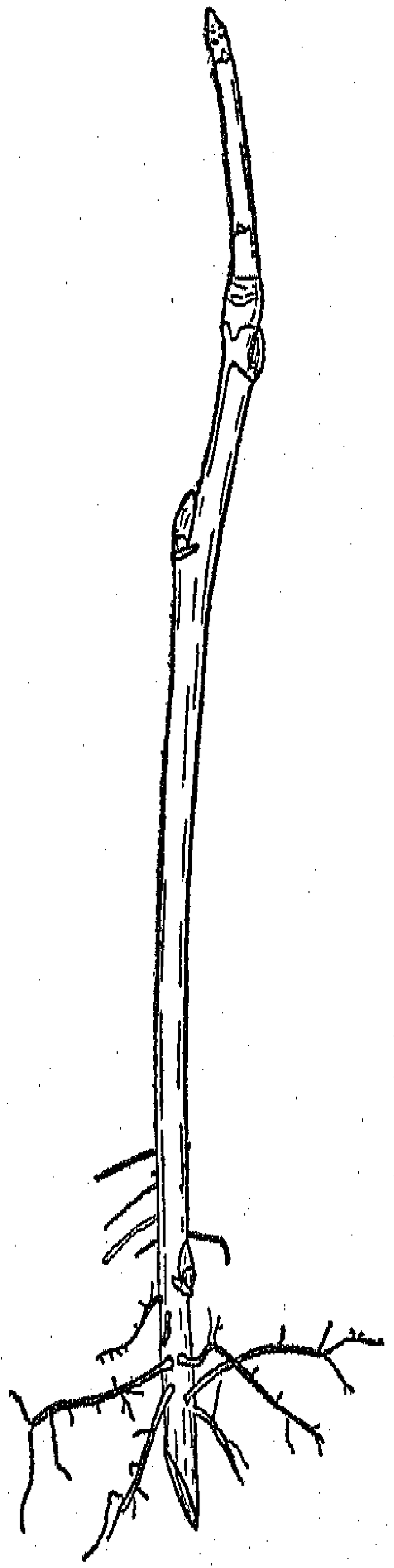


FIG. 163. — Autumn drawing of a black currant cutting taken the previous spring. (× 1.)

Small pieces of black currant bush,

or rambler rose, will also "strike" if you let them remain in the soil throughout the winter (Fig. 163). Such cuttings are best taken in the autumn.

In some bushes (e.g., blackberry and gooseberry) low growing branches often touch the soil, and these branches may put out roots of their own accord. If you have a gooseberry bush in the garden you can easily try this. Peg down a branch with a forked stick and cover it with soil. At the end of a year you will almost certainly have a new gooseberry bush which, however, will still be attached to the parent by the branch you pegged down.

In land plants the fragments that split off from the parents to form new plants are usually rather special. The tiny bodies which we call spores, and which we have seen are produced in large numbers by fungi, ferns, and mosses, are examples. In each case the spore grows into a new plant. In fungi this is exactly like the parent plant, but in ferns the new plant is not at all like the parent. You should turn to p. 41 and read again about the life cycle of the fern.

Many perennial plants reproduce asexually. The Shallot is a good example. If you plant a shallot firmly in the ground in February, it will grow into a typical onion-like plant with a tuft of leaves. Towards the end of May the original bulb will be found to have split up into several smaller ones, and by the end of June these will all have become swollen. The leaves now die down, and, in place of the original shallot bulb, there will be a group of five or six or more. The number will depend upon the richness of the soil and the nature of the season. The bulbs, if left in the ground, become more or less separate and next spring (or even during the autumn) each will begin to grow into a new shallot plant.

Potatoes reproduce asexually in a very similar manner. A potato tuber is really a stem, as is shown by the fact that it bears buds (the "eyes") and much reduced leaves (the ridges near the "eyes").

When planted in the ground the buds begin to sprout into branches that grow upwards and become the familiar potato tops. From their bases roots grow out into the soil. The food required to build the tops and roots comes from the potato tuber which will now be found to be much shrunken.

Soon, from the parts of the tops that are underground, thin white branches grow into the soil. These make no attempt to grow upwards but presently begin to swell at their tips. The swellings get bigger and bigger and gradually form potatoes. So now we have the parent potato plant surrounded by a number of new potatoes each connected to the parent by a long thin branch. If the potato plant were left in the soil, the thin branches would gradually rot away, so that next spring there would be a ring of new potato plants, perhaps a dozen or more, round the site of this year's plant.

In this way potatoes could rapidly spread over a piece of ground if there were nothing else to prevent them. Actually potatoes have many enemies, such as slugs, wireworms, beetles, and various fungal and other microscopic parasites. Also, potatoes left in the soil in England are usually destroyed by the winter frosts, though if a tuber happens to be buried fairly deeply it is likely to escape harm.

A number of plants reproduce themselves in a similar way. Below the ground horizontal branches arise from the stem and grow away from the parent plant. Sooner or later the tips of these underground stems come above ground and form new plants. The connection with the parent plant soon rots. Examples are perennial sunflowers, michaelmas daisies, and nettles.

Strawberries reproduce asexually in a most efficient way. During the early summer, branches called runners begin to grow from the main plant. Instead of growing upwards, these grow along the surface of the soil and away from the parents. When it is some distance from the parent, the tip of each runner turns upwards and begins to develop into a daughter plant. Roots grow from the tip of the runner into the soil and soon the daughter plant is well established. Usually this gives off another runner which forms a second plant further away from the parent. In its turn even this plant may send out a new runner, so that by autumn chains of daughter plants stretch away from the parent, but all are connected to it by the slender stems of the "runners". These rot away before the next season and the daughter plants become independent. A wild plant that behaves in the same way is the creeping buttercup, often found as a garden weed. The creeping stems of ground ivy (Fig. 164) put out roots at almost every node. Each section of stem, with its roots, is capable of growing into an independent plant.

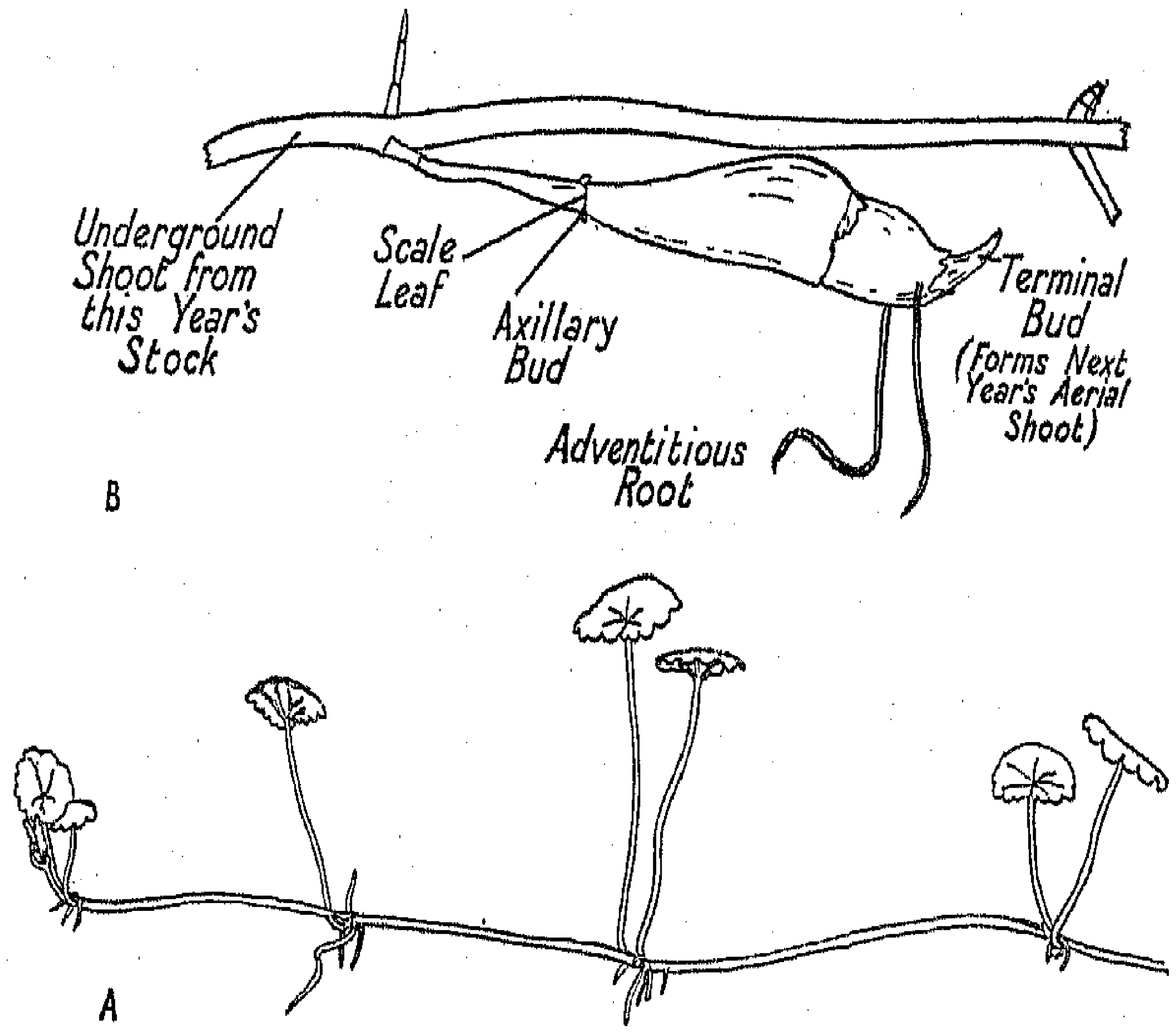

Underground Shoot from this Year's Stock
Scale Leaf
Axillary Bud
Adventitious Root
Terminal Bud (Forms Next Year's Aerial Shoot)
B
A

FIG. 164.—*A.* Creeping stem of Ground Ivy, putting out roots at the nodes. *B.* Underground stolon of Perennial Sunflower, drawn in winter. A single Sunflower will produce a large number of these stolons, each of which can give rise to a new plant from its terminal bud. The swollen part is full of reserve food material.

A slightly different type of asexual reproduction is found in the Crocus. Crocus flowers grow from short upright stems called corms. A crocus corm has a covering of papery leaves and has one or more fat pointed buds at the top. In this state it is planted in the ground. The swollen stem contains the food that in early spring enables the bud to grow into the overground leaves and the flower. The old corm has very little food left and begins to shrivel. After the flower has been pollinated the ovary ripens into a fruit and seeds are scattered in the normal way. The region where the leaves grow out from the old corm now begins to swell because food is passed down into it from the leaves above. Gradually it gets bigger and bigger and comes to resemble the parent corm. Finally, in summer, the leaves die down and wither to form a papery covering for the new corm. At the top of the new corm is a bud, and underneath it is the old corm, now quite withered (Fig. 165).

Many animals are capable of asexual reproduction, but mostly such animals are microscopic or else live in the sea and are unfamiliar to us. We have seen (p. 100) that the freshwater *Hydra* reproduces asexually when there is plenty of food available, and also we saw that you can "take cuttings" of *Hydra.* It is said that earthworms have a similar power to grow into new worms if they are cut into two pieces, but I am by no means sure of this. Certainly I have seen the head end of a worm that had been cut into two growing a new tail, but I am very doubtful whether the tail end would grow a new head. Perhaps you would like to experiment?

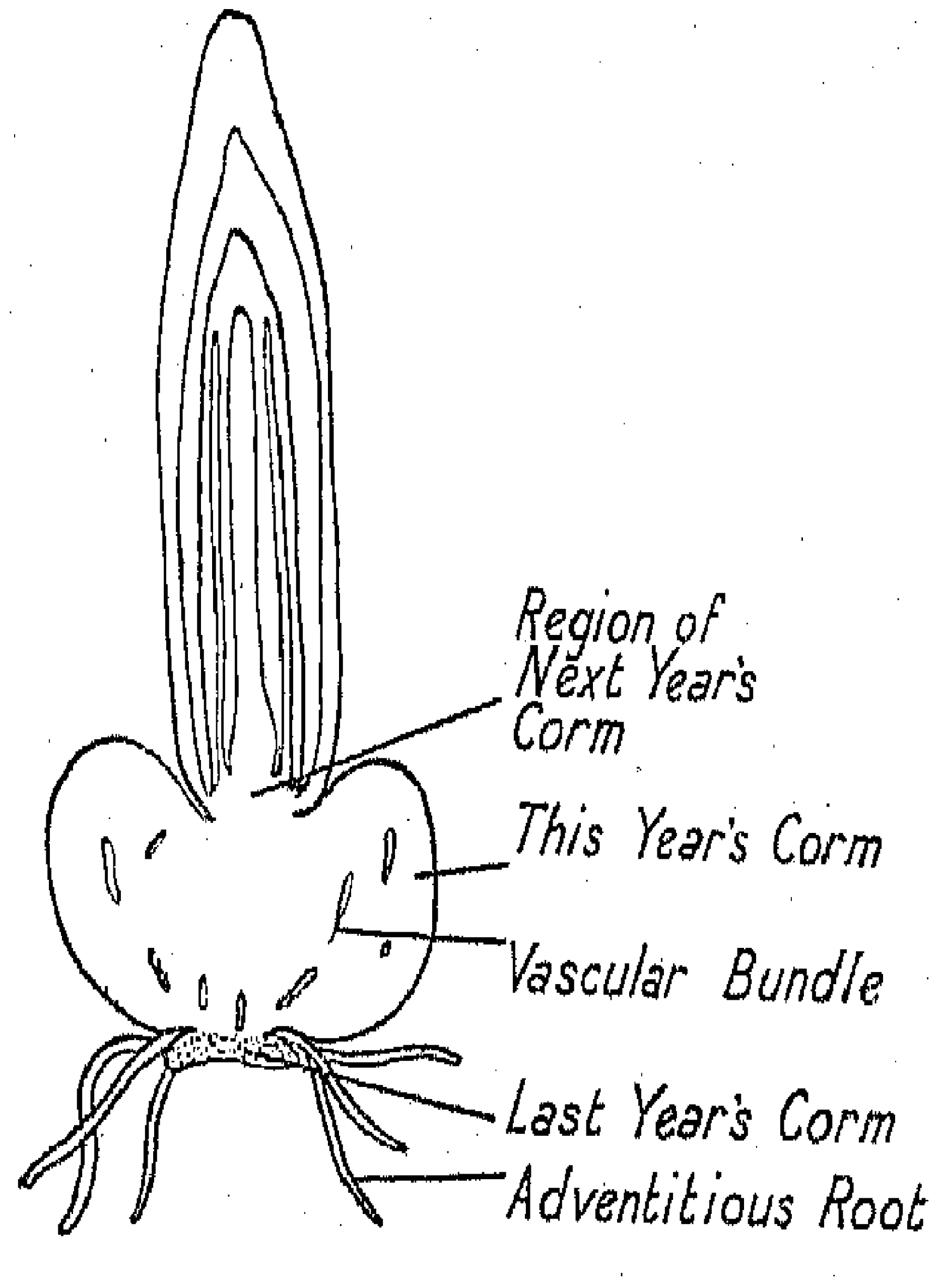


FIG. 165.—Longitudinal section of Crocus corm with papery covering of dried leaf bases removed.

Starfishes live only in the sea, but you may occasionally come across them when you are on holiday, though you will have to paddle to find them. Each starfish has five arms. Quite often an arm gets broken off. The starfish can easily grow another arm, but what is of greater interest to us, the arm may sometimes grow a new starfish, a process which resembles closely the growth of plants from cuttings.

Sexual Reproduction

The essential difference between asexual and sexual reproduction is that, while in asexual reproduction the fragment split off from the parent is capable of growing *by itself* into a new organism, in sexual reproduction it must first join with another fragment before it can grow. The particles used for sexual reproduction are called gametes—a word which means "marrying cells". There are two distinct kinds of gametes, called Eggs and Sperms. Eggs are large and cannot move about. They can often be seen quite easily with the naked eye, e.g., hens' eggs, butterflies' eggs, and frog spawn. The sperms are very, very small indeed, far too small to be seen without a microscope. They vary in shape in different plants and animals, but, except in the group of flowering plants and a few other instances, they can always move about. Sperms are attracted to eggs of their own kind. Eggs, of course, are normally produced by females, and sperms by males. However, in some groups of organisms we have seen that the eggs and sperms are produced by the same individual (e.g., snails, *Hydras*, and worms). Hence we cannot speak of a male earthworm or female snail, although we can speak of the male parts or the female parts of a worm or snail. Such creatures as these, that produce both male and female gametes in the one organism, are said to be *hermaphrodite* (herm-aff-roe-dite).

Now, normally an egg cannot grow into a new plant or animal by itself. It must first be united with a male gamete (sperm) of its own kind. This union of male and female gametes we have seen (p. 19) is called fertilisation, and many of the structures associated with sexual reproduction are present to ensure that the union does take place.

In animals, fertilisation of the eggs may take place either outside the animal's body or inside it. A good example of animals in which fertilisation takes place outside the body is provided by frogs. The way in which the eggs and sperms are laid into the water has been described on p. 70.

The eggs are the familiar frog spawn, but the sperms are too small to be seen except under a strong microscope. Then they are seen to be rather spear-shaped. The tail is capable of lashing movements, so that the sperms can swim through the water and seek out the eggs with which they unite, one sperm to each egg. This completes the act of fertilisation and the eggs begin to develop.

The development of a frog's egg is quite easy to follow, if you place a few in a dish of water. Do not have too many together in a small dish since they may use all the oxygen present, and die. When it is freshly laid the egg, inside its jelly, is more or less spherical. It is black in colour with the exception of a yellow zone which is always at the bottom of the egg. At first the egg is quite smooth. Soon a furrow appears that runs right round the egg and divides it into two halves. This is followed by another furrow at right angles to the first. Other furrows appear rapidly, and the surface of the egg becomes much divided. These divisions correspond to divisions of the inner material of the original egg. The area of yellow gets smaller and smaller, and soon disappears. The developing egg now gradually changes shape, and in a few days is rather flat and long. It then begins to move about in its egg membrane. Shortly afterwards the embryo, as it is now called, makes its way out and comes to rest on the jelly as a young tadpole.

Fertilisation of eggs by sperms takes place outside the body in most water animals. In the case of land creatures, external fertilisation is usually not possible because the eggs and sperms would dry up. To surmount this difficulty, the eggs are usually fertilised while they are in the body of the female. In order to make this possible, male animals are usually provided with some means of passing the sperms into the body of the female. In spiders (p. 184) this takes the form of specially altered palps. In most insects, the rear end of the male's body possesses a special device that can pass the sperms into the female's body. To do this, the male and female insect have to remain united or "copulate" as we call it. In the summer you will often see beetles, dragonflies (Fig. 98), butterflies, and other insects, mating.

In MAMMALS (e.g., dogs, rabbits, cows, man, etc.) the sperms have also to be transferred from the body of the male into the body of the female. Male mammals have a muscular organ, called the penis, for this purpose.

As soon as an egg inside the female's body has been fertilised, it is usually enclosed within a protective shell and then passed to the outside world. The purpose of the shell is partly to prevent the egg from drying up, and partly to protect it from microscopic enemies. Drying up is one of the greatest dangers facing living material on land, and the smaller the amount of material, the more quickly it is likely to dry up. Therefore it is not surprising to find that the tiny eggs of insects are, in many cases at least, supplied with a fatty layer that makes them waterproof. Snakes' eggs are protected by a tough leathery jacket, while you will be familiar with the shells of birds' eggs.

Some animals do not lay their eggs when these have been fertilised. Instead, the eggs are kept inside the animals' bodies where they develop into young which, in due time, are "laid", or born as we usually call it. All the common mammals belong to this group, though there are Australian forms that actually lay eggs like birds.

The habit of giving birth to live young instead of laying eggs occurs in other groups besides the mammals. We saw that this was true of the aphides (p. 162), and, although most snakes lay eggs, the English viper keeps her eggs inside her body until they hatch and so she gives birth to young snakes.

Flowering Plants have a form of sexual reproduction that differs in no real way from that of animals. I have already referred to it in Chapter 2, but it will be convenient if I repeat the main outlines here. The eggs are made in the ovary, and are contained inside the ovules. The eggs remain here waiting to be fertilised by male cells that correspond to sperms. The male cells are produced by the pollen which itself is made in the anthers of the stamens. When a pollen grain falls on to the stigma of its own kind of plant it germinates; that is to say, a tube grows out from it. This pollen tube grows down the style into the ovary and makes its way to an ovule. In the tip of the pollen tube is the male element which then joins with the egg inside the ovule and so fertilises it. The egg then begins to grow and soon forms a baby plant, still inside the ovule. As the baby plant grows, the ovule swells and its walls dry up. Soon the whole structure, ovule and young plant, is ripe, and it now forms a seed (see Chapter 23).

If you now consider plants and animals in connection with what I have told you about reproduction, you will see that old animals and plants are constantly dying and young ones being born. In their turn the young ones grow older, reproduce, and die, to be followed by their offspring. In this way the continuance of a species or race is achieved, and obviously it is of the utmost importance for the species that as many members as possible shall live long enough to reproduce. This is why we find that plants and animals will do their utmost to reproduce before they die. The fly *Volucella bombylans* which enters the nests of bumble bees in order to lay its eggs, is sometimes stung by one of the bees. In this event the fly immediately commences to lay and continues to do so in its death throes, until all the eggs are laid. In plants, bad conditions for growth nearly always result in the production of masses of flowers, although these may be small. You will find dandelions and

clover and buttercups flowering on lawns that are regularly cut once a week. In towns, in the cracks between pavement stones, or in the gap between the pavements and walls, you will frequently find tiny plants have taken root, especially *Poa annua* (Fig. 12) and shepherd's purse. Although these plants are very stunted, and obviously not prospering, they will most likely have an abundance of flowers. They are, we say, struggling to complete their life cycles, to reproduce and leave seeds to start off the next generation of plants.

If you reflect you will realise that all the activities of plants and animals are directed towards completing their life cycles and leaving young to replace them. When they have completed their life cycles (by reproducing), many plants and animals die almost at once. Any of the annual plants in the garden (peas, groundsel, shepherd's purse) show this quite well. Most female insects die very shortly after they have laid their eggs, and male insects may die as soon as they have mated with the females. Male hive bees (drones) actually die in the mating act, but they have completed their life cycles and made provision for more bees to follow them.

On the other hand, we find that in some animal groups the parents normally continue to live after the young have been born, and this makes parental care possible (e.g., in man, many birds, cats, sticklebacks).

CHAPTER TWENTY-EIGHT

The Interrelations of Plants and Animals

WE have seen in earlier chapters that plants and animals are, at least to some extent, dependent on one another; that some plants, for instance, require insects to pollinate them, while others rely upon animals to distribute their seeds; and that plants growing in the same area compete with one another for space, both for their roots and their shoots. In this chapter we shall be concerned with some other ways in which plants and animals interact with one another.

Parasites on Plants: Galls

While you have been observing plants, you may have seen peculiar structures on some members of a species which were absent from other plants of the same kind. The structures I am referring to are made of the plant's own tissues but are obviously unlike any of the plant organs that we have studied. They are neither stems, leaves, flowers, nor buds, but are outgrowths of the normal tissues, much as warts are outgrowths of human skin. These structures are called galls.

Many different galls are to be found on oak trees. The best known are perhaps the MARBLE GALLS (Plate VIII), which are most often found on young trees or on the lower branches of older trees. The young Marble Galls are yellowish brown spheres between ½ inch and ¾ inch in diameter made of corky material and quite light in weight. As they grow older, they become a darker brown. The outer skin is fairly hard. Sometimes in an old gall you will be able to find a small round hole in the surface. If, with a sharp knife, you halve the gall along the line of this hole, you will find that it leads into a tunnel which runs to the centre of the gall. There it ends in a spherical chamber which is enclosed by a very hard wall.

The young galls (light in colour) will be found to have no

hole in the outside skin. When one of these is split open, the explanation of the tunnel becomes evident, for curled up in the central chamber will be found a fat pearly white grub. This is the larva of a species of wasp, the Marble Gall Wasp. Towards September or October the grub turns into the wasp which bites its way out, thus forming the tunnel. All the wasps are females, and these proceed to lay eggs on fresh oak buds which, the following May, begin to develop into new galls. The galls are especially plentiful on young oak trees five or six feet high, such as you may often find in hedgerows. Collect a number of the galls in August and place them in jam-pots with muslin over the top. You should be able to obtain the adult wasps and, if you supply them with fresh oak twigs, may even see them pierce the buds to lay their eggs. The wasps are small black creatures quite unlike the black and yellow stinging wasps of the genus *Vespa*.

You will often find oak leaves whose under surfaces are more or less thickly studded with little circular disc-like galls having a raised part in the centre (Fig. 166). These are the COMMON SPANGLE GALLS. You will also find them on dead oak leaves as late as April, though, after the leaves have fallen, the Spangle Galls tend to drop off them.

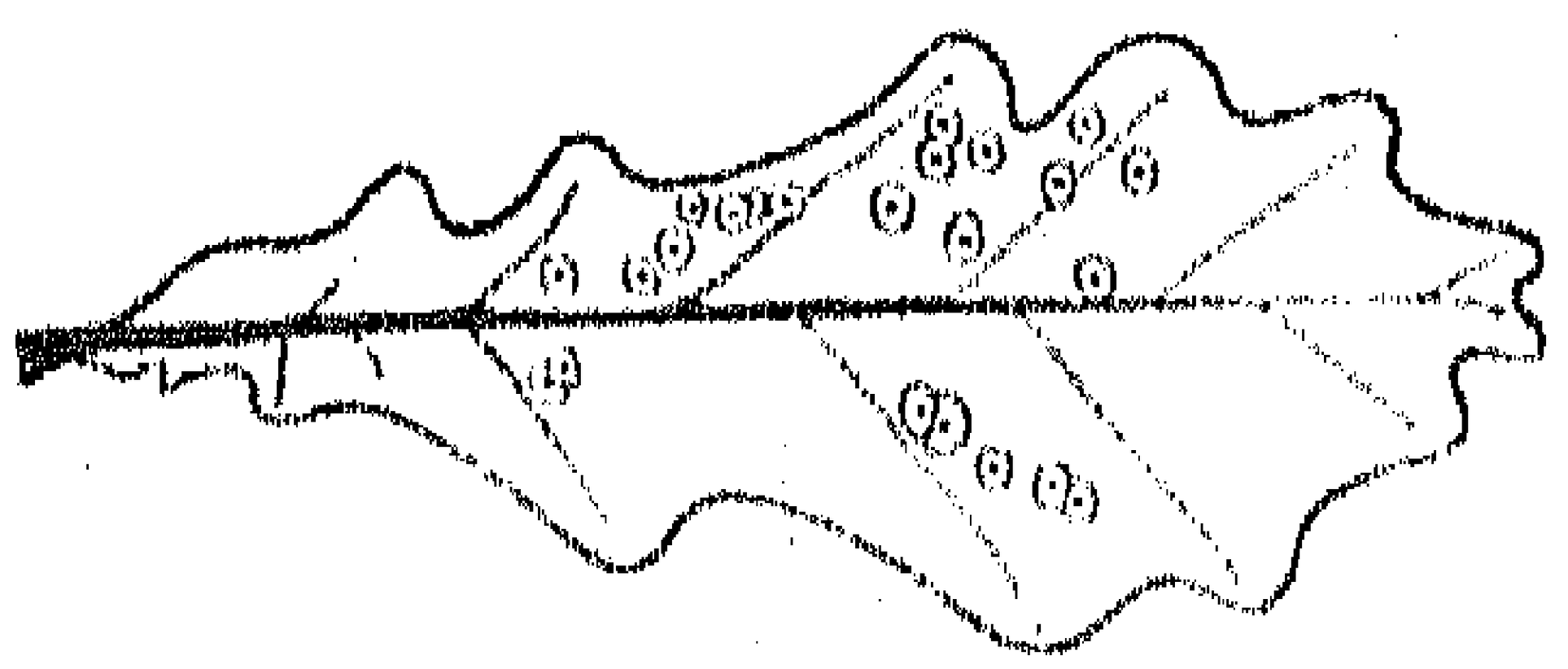
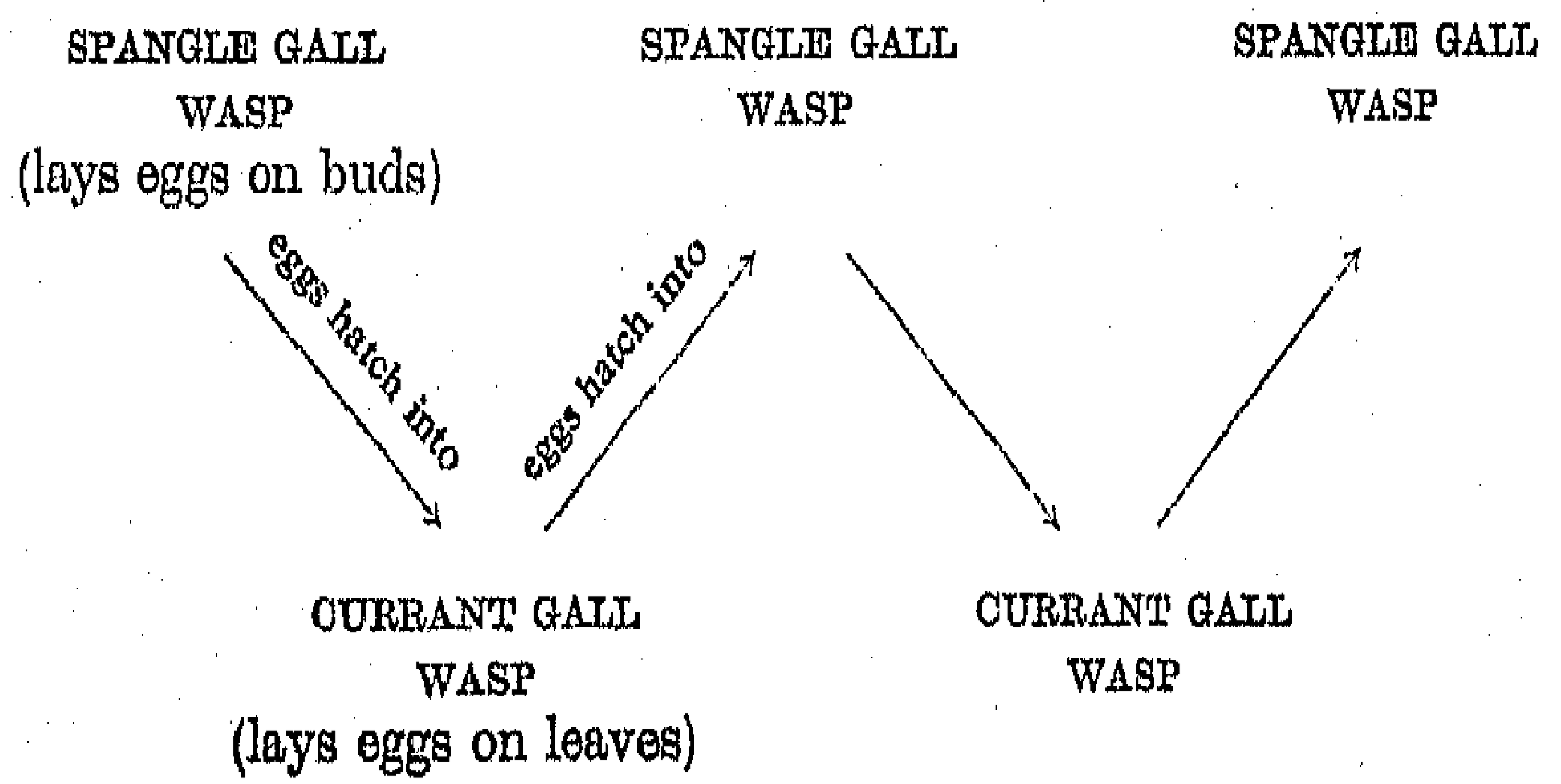


FIG. 166.—Spangle galls on oak leaf, ×½.

The Spangle Gall Wasps emerge in April. They are all females and they lay eggs in the young oak buds, buds that would have formed either flowers or leaves. In time, the result of this is the formation of an entirely different gall, the Currant Gall of the oak, either on leaves or more usually on the male catkins. In June, male and female wasps of quite different structure from the Spangle Gall Wasps hatch from the Currant Galls. The females of these Currant Gall Wasps now lay eggs in leaves, and these eggs lead to the formation of new Spangle Galls.

This is a most interesting phenomenon. The Spangle Gall Wasp lays eggs which turn into Currant Gall Wasps, and these lay eggs that grow into Spangle Gall Wasps again. The two kinds of wasp are quite unlike each other, and yet, since one gives rise to the other, they must belong to the same species. This type of life cycle where there are two quite distinct types of an organism, and each type regularly gives rise to the other, is called an *alternation of generations.*



There is an alternation of generations in the life cycle of the oak gall wasp that causes the OAK APPLE. The Oak Apple is a large green, rather fleshy, gall, about 1 inch across, which appears early in May, developing from a bud (Plate VIII). By early June the Oak Apple is mature and is now streaked with pink. Inside it are many small chambers, each with a white grub. The grubs eat their way to the surface and turn into small dark coloured wasps. Both males and females are produced. The females are without wings and after mating crawl down the trunk and lay eggs in the roots. In time, these cause the formation of Root Galls, which are clusters of hard yellowish brown structures (Fig. 167). Inside each is a single cavity with a developing grub. At the end of January, each grub will turn into a wingless dark brown wasp which will eat its way out, crawl up the trunk of the oak tree and lay eggs in buds to start new Oak Apples developing in May.

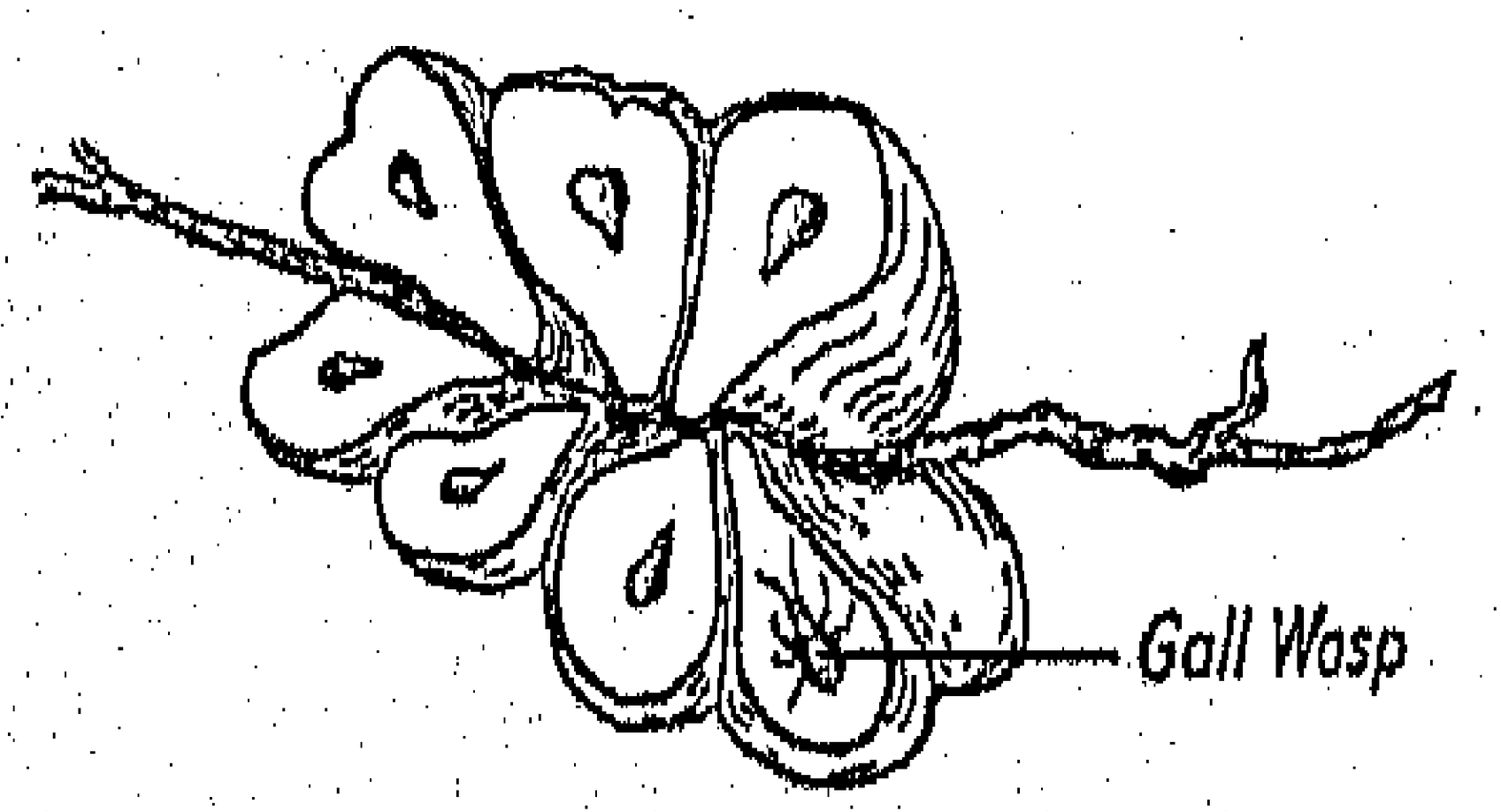


FIG. 167.—Galls of the Oak Apple Gall Wasp (*Biorrhiza aptera*) on the roots of oak. The galls are shown sliced through, to expose the chambers in which the wasps develop. One wasp is seen emerging, ×1. (Re-drawn after E. W. Swanton.)

There are many other galls that may be found on oak trees. Plate VIII shows a CHERRY GALL and Fig. 168 a specimen of the gall wasp that causes it.

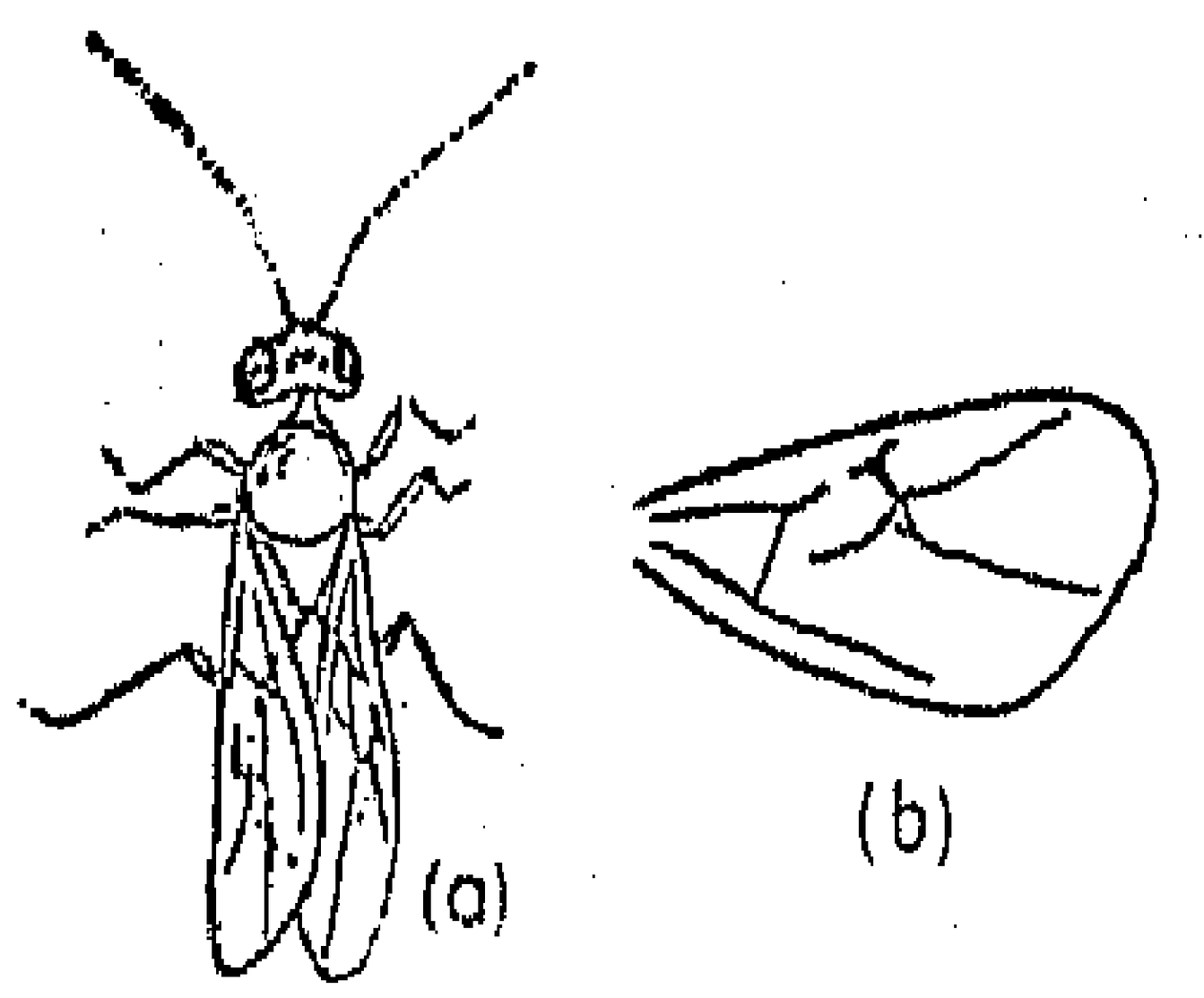


FIG. 168.—(*a*) Cynipid gall fly hatched from Cherry Gall on oak; (*b*) wing of (*a*) to show the vein pattern. (Enlarged.)

On Wild Roses there is frequently to be found growing a very striking gall. It is called a BEDEGUAR (bed-e-gar), or in some counties Robin's Pin-Cushion, and at first it looks like a bundle of brightly coloured moss. Shades of red are especially prominent. If you obtain one you will find its central portion is solid and hard. Split it open with a knife and inside you will see many pearly grubs each lying in a separate chamber. The grubs have developed from eggs laid by the Rose Gall Wasp in a leaf bud. The presence of the developing larvæ causes the bud to form into a gall instead of into a branch as it would normally do. The adult wasps come out of the gall the following spring. In addition to the Rose Gall Wasps, several other types of insects usually inhabit each Bedeguar.

Many other plants produce galls in response to the presence of other organisms, which may not necessarily be wasps. Types of beetles, two-winged flies, fungi, and mites may all produce galls. "Witches' Brooms" (see p. 57) are caused by a fungus. The curious red Nail Galls common on sycamore leaves are caused by mites, as are the Big Bud Galls on blackcurrants. Sawflies are the cause of the brilliant red kidney-shaped galls found on willow leaves (Fig. 169).

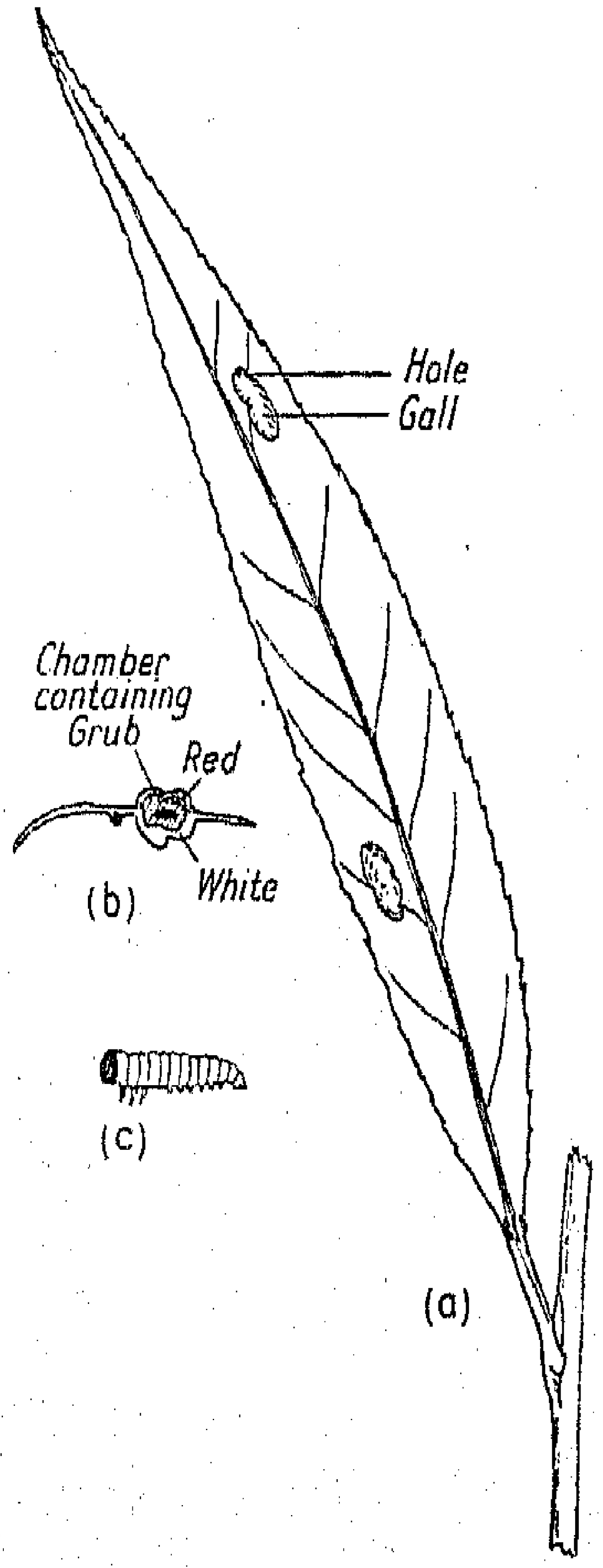


FIG. 169.—(*a*) Bean Galls on willow; (*b*) section through the gall; (*c*) saw-fly maggot from the gall, (*a*) and (*b*), ×½; (*c*), ×3½.

Parasites on Animals

If caterpillars of the Cabbage

White butterfly are collected in September and kept indoors, a number of them will fail to pupate. These at first seem sickly and limp, and then, in a few days, a number of tiny maggots will burst through each caterpillar's skin and begin to weave a deep golden yellow silk. The caterpillar will die and shrivel but around its dead body will be from twenty to thirty golden cocoons. If you keep a number of caterpillars in jam-pots, you should be able to watch the small grubs spinning.

That these smaller creatures have actually been living inside the caterpillars is not difficult to prove, for if you select one of the more sickly looking caterpillars and cut it open you will find the maggots inside it. They have been living on the caterpillar's internal organs. The question to be answered is: how did they get there?

Allow several caterpillars to pupate in a jam-pot. Some of them are almost certain to provide you with a supply of the golden cocoons. Fix a piece of stout cloth over the open end and place the pot outside in a sheltered spot. Protect the top from direct rain, with a piece of wood or several bricks. It is even better to sink the pot in the ground to the rim and protect the mouth. Examine the pot next spring at intervals of a few days, and about May you should find in the jam-pots a number of small black insects. These are Ichneumon Wasps (ik-new-mon) of the genus *Apanteles* (a-pan-tel-eez). Normally they would fly away and seek out young caterpillars of the Cabbage White butterfly in which each *Apanteles* would lay from twenty to thirty eggs. The eggs would hatch inside the caterpillar's body and give rise to the white maggots I have already described.

A somewhat similar instance of a wasp laying its eggs in another insect's larva, is provided by a slender black species that lays eggs in the maggots which appear when a dead animal or piece of meat is left exposed to the air in May or June. This was first brought to my notice when I had a dead rabbit and a dead rat in a shady corner of the garden. I was hoping to obtain carrion beetles. The dead animals were covered with a wire netting cage to protect them from cats and rats. Soon, of course, the corpses were teeming with maggots of blow flies. After about a fortnight, I was searching for beetles in the mass of maggots and saw a number of slender black "wasps" actively crawling over the maggots. Then I noticed that some of the wasps were actually "stinging" the maggots with their egg-laying tubes (*ovi-positors*). I collected a number of maggots, many of which had burrowed into the soil to pupate, together with some soil, placed them in a jam-pot with a piece of cloth as a lid. During the first week of July a number of the black wasps hatched out and crawled on to the muslin covering the jar.

A rather similar experience arose out of a fishing contest in which I was competing. The place I was drawn to fish from was in the middle of a bed of nettles. At the close of the contest, as I was packing up, I noticed a number of blackish caterpillars on the nettles, each caterpillar lying in the middle of the top surface of a nettle leaf. I put several in a tobacco tin. When I got home, I found two large white maggots in the tin in addition to the caterpillars. This puzzled me; but I concluded they must be fishing maggots that had got in. I

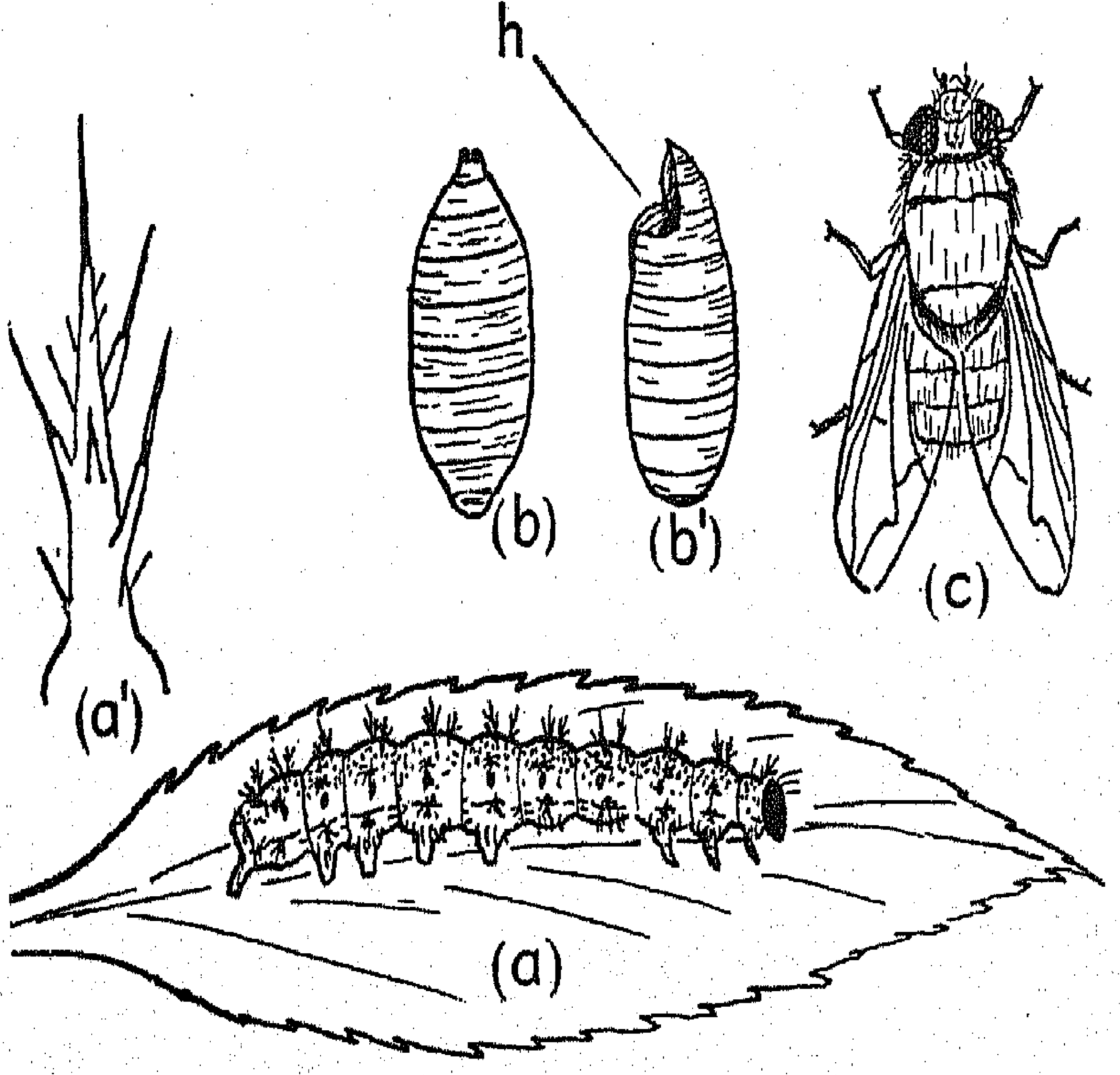


FIG. 170.—(*a*) Peacock Butterfly caterpillar, lying along the midrib of a nettle leaf. (*a'*) a single spine from the body of the caterpillar. From the caterpillar a white maggot emerged which soon pupated to give the puparium (*b*); (*b'*) shows the empty puparium after there had emerged from it the Tachinid fly (*c*). (*a*) ×2, (*b*) and (*c*) ×3, (*a'*) much enlarged.

thought no more of it and put one of the caterpillars in a glass tube to take to one of my friends—they were caterpillars of the Peacock Butterfly. When I handed over the caterpillar, there was another of these maggots in the tube. Then it became obvious that these maggots had been living inside the caterpillars.

I kept some of them and in a day or two they turned into pupæ not unlike the pupæ of blow flies, and finally out of each hatched a two-winged fly (Fig. 170). I found out later that it is well known that these particular flies lay their eggs inside the caterpillars of Peacock Butterflies and, when the eggs hatch, the larvæ grow inside the butterfly caterpillars, feeding on their tissues just as the ichneumon wasps do.

In all the foregoing examples, we have been concerned with instances where one organism has lived either on or inside the body of another organism, to which it has caused some harm. In such associations the organisms that cause the damage are called *parasites*, while the organisms that suffer the damage are called *hosts*. Thus the oak tree is the host of many gall wasps, while *Apanteles* is a parasite of the Cabbage White butterfly.

Many of our beetles, especially the dung beetles, will be found to be covered with mites. The mites hang on so tightly that it is difficult to dislodge them, but a puff of tobacco smoke will cause them to run wildly over the body of the host. Similar mites occur on the queens of certain bumble bees in spring. The mites apparently pierce the skin of the insect on which they dwell and suck its juices.

Man himself may act as a host to many different parasites. Fleas and lice are well known, but there are many others which live in his blood, especially very small ones such as the bacteria and viruses that cause diseases.

Living Together

In instances of parasitism one organism alone benefits, and this benefit is at the expense of the host. There are associations between living things where both members benefit. They are partners, as it were, and the activity of each one helps the other. An association of this kind, where two organisms live together for their mutual benefit is called *symbiosis*, a word that means "living together".

Those curious plants called lichens provide excellent examples of symbiosis. The **Pixy Cup Lichen** is a common one often to be found growing on dead tree stumps, especially where the ground is rather damp, as in woods. With a hand lens there is little to be seen. With a microscope it is not difficult to perceive that the lichen is built up of two distinct partners, a fungus and an alga, and this union of two plants, each quite delicate by itself, makes a compound plant capable of surviving and growing slowly in the most difficult places, though it is said that many lichens have disappeared from the large towns because they cannot endure the chemical laden dust which is always settling from the atmosphere of such places.

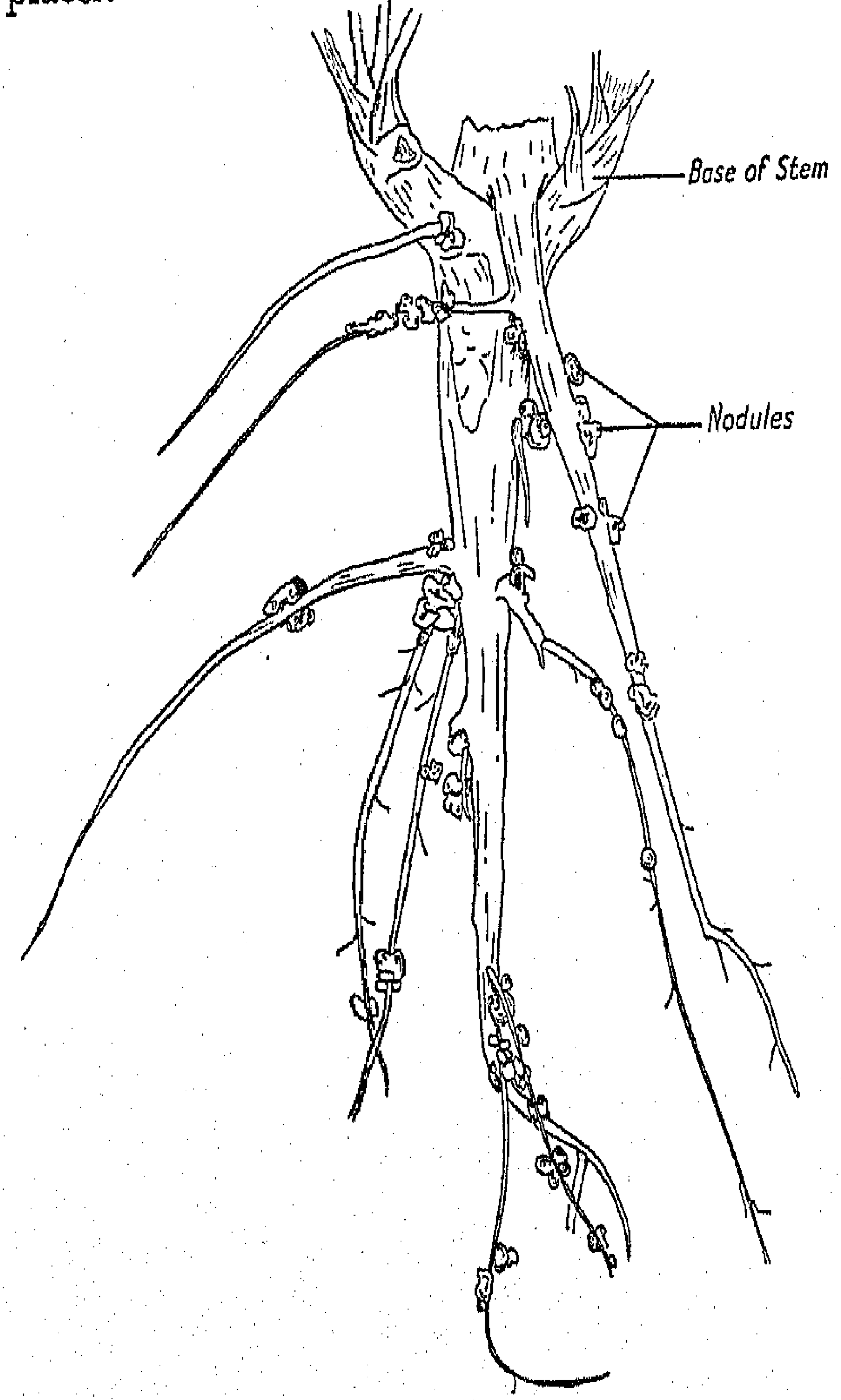


FIG. 171.—Root of lupin, showing nodules which are colonies of bacteria, ×½.

If you dig up any member of the PEA-FLOWER FAMILY (p. 26), you will find wart-like swellings on the roots (Fig. 171). When you cut across such a swelling with a razor or sharp knife, the central area may appear reddish-purple. Each swelling or nodule is a gall produced by the plant in response to an invasion of its roots by bacteria. The bacteria obtain their food from the plant, but they are not parasites, because they give something in return. As you are aware, plants take certain substances from the soil, and that is why we add fertilisers to obtain good crops. One of the most important substances required by plants is nitrogen—a gas which constitutes about four-fifths of the air we breathe. It is present, too, in the tiny spaces between the soil particles. Unfortunately plants cannot use nitrogen in its free state, they can only utilise it when it is combined with other substances to form such salts as nitrates. That is why nitrates are used as fertilisers.

However, the bacteria in the root nodules have the power to turn the nitrogen gas present in the soil atmosphere into a form which plants can utilise, and they do this as their share towards the partnership. In return, as I have stated earlier, the plant supplies food (such as sugar) for the bacteria.

This symbiosis between the members of the pea-flower family and bacteria supplies the explanation to a fact you may have noticed, that gorse and broom are often to be found growing on poor soil on commons and heaths where little else grows. It is also one reason why farmers find it profitable to grow clover (another member of the pea-flower family) on their land and then plough it in. When it rots, it enriches the soil for future crops, particularly with nitrogen in a form that plants can use.

As a final example of symbiosis I will describe the interaction between ANTS and APHIDES (p. 161). You will remember that when an aphid is feeding it pushes its proboscis into a tender plant stem and sucks up sap more quickly than it can deal with it, and so at intervals it gives off from its anus a glistening drop of clear sweet liquid, honeydew. Usually, when this appears the aphid gives a quick jerk of its rear end and throws the drop some distance.

If you find plants with aphides feeding on them, you are almost certain to notice ants running hurriedly here and there. Occasionally an ant will halt at an aphis and caress it with its feelers. If you have patience to watch for some while through a hand lens, taking care not to disturb the insects, you may see an aphis which is being caressed by an ant produce some honeydew. But now, instead of kicking the sugary drop away, the aphis allows the ant to drink it. The ant will then go on to other aphides.

In return for this supply of honeydew, the ants are reputed to look after the aphides and protect them from attack by other small insects. They are said to carry the aphides and place them on suitable parts of plants, but I have not myself seen this occur. In some species of ant there is no doubt that its members build shelters for the aphides; while in other species, the ants harbour the aphides in their nests during the winter. There is probably much yet to be learned about ants and the many "guests" they harbour in their nests.

Interdependence of Animals and Plants

When we consider together all the animals and plants in an area, a different kind of relationship becomes evident. For instance, the presence or absence of a particular plant may determine whether other plants can grow. Most of you will have walked through woods where there is little or no undergrowth. Some BEECHWOODS are particularly good examples of this. The beech trees form such a dense roof of leaves that in the summer little or no light penetrates through to the floor and the immense quantities of leaves which fall often decay but slowly, and make the surface layer acid. Nevertheless, most beechwoods do have characteristic plants growing in them, though many of these plants produce their leaves and flowers early in the year when the trees do not cut out so much light. The curious Bird's Nest Orchid grows in beechwoods and is able to obtain its food from the decaying beech leaves.

The leaves from many coniferous trees (e.g., pine, cypress) take a long time to rot when they fall to the ground, and, if they accumulate, prevent grass growing (see p. 255).

Many FUNGI grow in association with trees, either as parasites (e.g., Honey Cap Agaric, bracket fungi, Plate I) or else in symbiosis with them. Most plants have a thick growth of root hairs just behind their root tips (see p. 226). Through these they absorb water and food substances from the soil. Many forest trees do not have these root hairs; instead they have a fungus partner which serves the same purpose. The hyphæ of the fungus grow round the root tip, either inside it or as a tightly fitting jacket outside it, and do the absorbing for the plant, obtaining from it other foods in return. When the fungus bears fruiting bodies, usually in the autumn, the toadstools appear underneath the tree. The brilliant scarlet caps of the Fly Agaric, with their scales of white, are always found beneath trees, especially birches or firs.

The beetle *Rhagium bifasciatum* (ray-ge-um by-fash-e-ate-um) shown in Fig. 172 develops only in the stumps of pines and other trees, from which the adult can be obtained by splitting the wood with a chisel. Certain beetles can live only in the bark of dying trees, in which the sap is drying out. The beetles (*Hylurgops palliatus*) shown in Plate VI, were living in the trunks of larches that had been blown down in a gale the previous autumn. Similarly, various other insects (e.g., butterflies and moths) which, especially as caterpillars, are restricted in their diets, can only be present in regions where the food plants grow. The presence or absence of the food plants themselves will depend on the soil, the rainfall, and other factors such as nearness to the sea and the slope of the land.

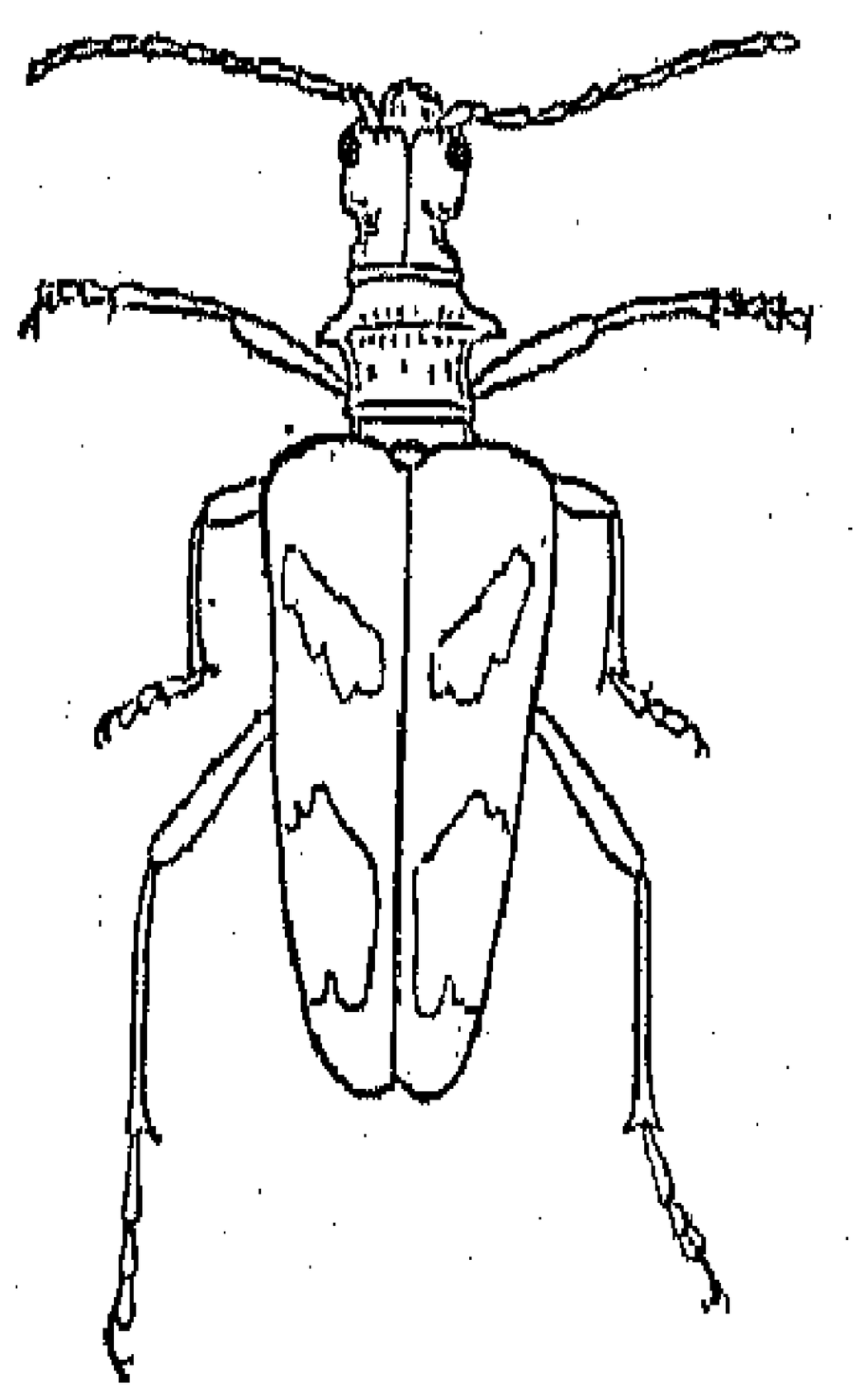


FIG. 172. — Longicorn beetle, *Rhagium bifasciatum*, ×1½.

The LARGE BLUE BUTTERFLY, which occurs in the Cotswolds and Cornwall, cannot complete its life cycle unless the caterpillar is adopted by ants of certain species. The ants carry the caterpillars to their nests in August and feed them on ant larvæ. The caterpillars remain in the ants' nests until the following June when they emerge as perfect adult insects. Hence, the Large Blue can only exist in areas where the appropriate ants live, and also where wild thyme grows, for the newly-hatched caterpillars feed on the flowers of this plant for the first three weeks after hatching from the eggs.

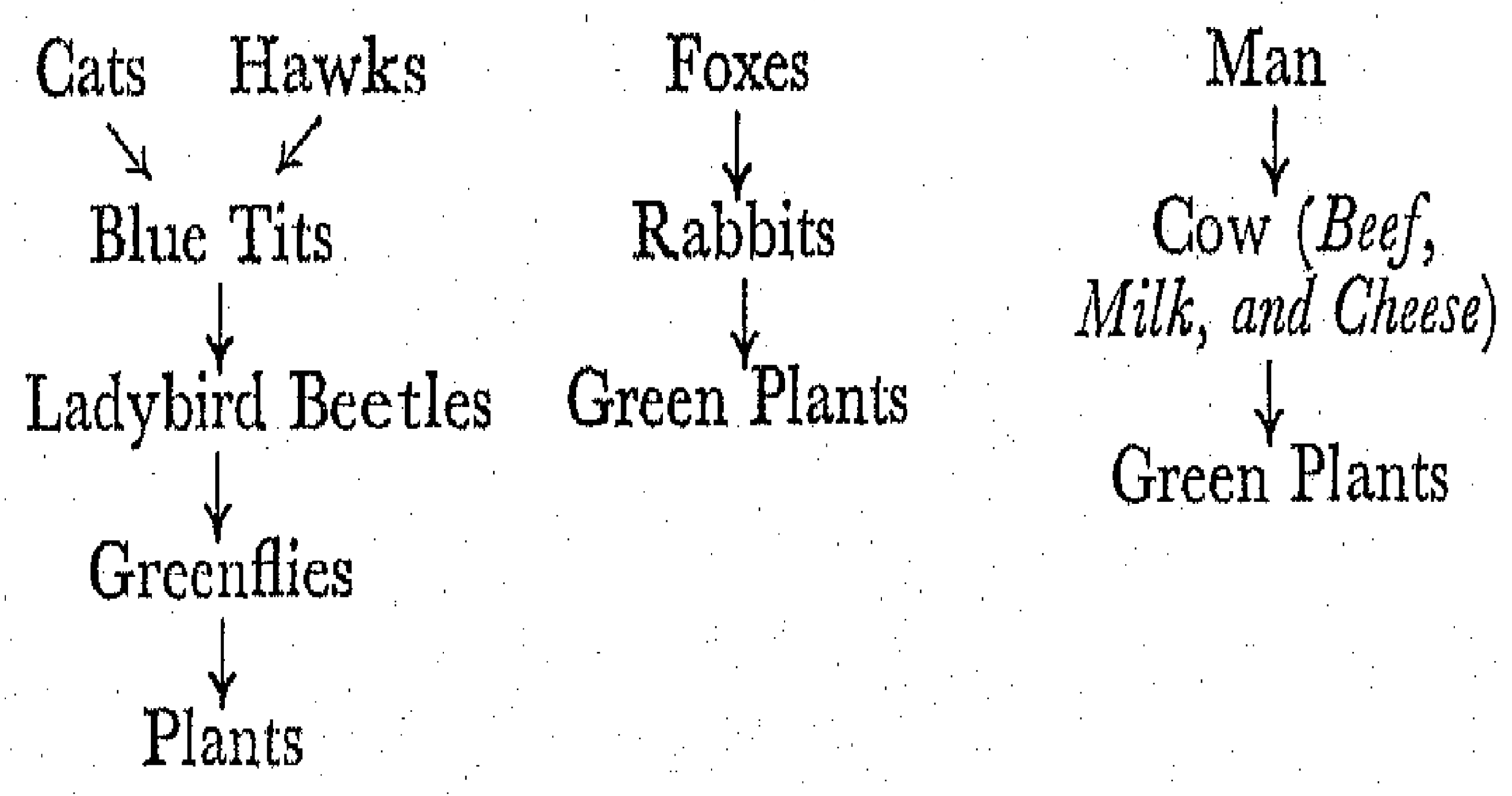
The presence of a large WILD RABBIT population may prevent certain plants growing in an area which otherwise would be suitable for them. Rabbits prefer some kinds of food to others, and certain plants they will not eat at all (e.g., bracken fern, elderberry, nettles), nor are they very fond of blackberry. It is no uncommon sight, where rabbits are really abundant, to see stretches of hillside nibbled as close as a lawn. If small woods occur, these end abruptly, without the young trees and seedlings one might expect on their edges. This is because rabbits nibble off the seedlings before they have time to establish themselves. In the open pasture, only those plants that can react to the constant nibbling by putting out fresh shoots along the ground, succeed in establishing themselves.

That bracken is "rabbit resistant" accounts for the immense stretches of bracken-covered land throughout the country. Once it has become established, the bracken can rapidly extend its area by means of its underground stems, and there is nothing to check its spread.

The wild rabbit is a good source of food for other animals, particularly foxes, weasels, and stoats. Rabbit droppings form a source of food for certain beetles, and young rabbits are preyed upon by owls and hawks.

It is easy to see that if there are many rabbits in an area, it is likely that there will also be correspondingly large numbers of these other creatures that feed on them. The series:—green plants—rabbits—foxes, etc., form what we call a FOOD CHAIN.

You will be familiar with several food chains. The blue tits in the garden eat ladybird beetles, whose grubs in turn eat greenflies which feed on various plants. And the blue tits themselves are liable to be caught and eaten by hawks, and, in towns, by cats. So we have



You will have seen thrushes pulling worms from the lawn, or perhaps smashing snails on a large stone. Snails feed on green plants. So do worms, though not until the plants are beginning to decay. To take an example which concerns us more directly, men feed on cows, either on the meat itself or on milk products such as butter and cheese, and cows feed on green plants.

Notice that I have stressed that in each of these food chains the end link is green plants. Note also that each link is usually more numerous than the one feeding upon it. There are more snails than thrushes, more rabbits than foxes, and more blue tits than hawks. You can work out food chains for yourself by observing what different animals eat, but to work out a food chain completely is a difficult task. There are many side branches I have left out in the examples given above. Foxes eat other creatures besides rabbits—field mice and young birds for example, and possibly also large beetles and earthworms. Some of these are eaten by owls, so that foxes compete with owls for their food supply. You will realise that in any given area the lives of a considerable number of different plants and animals are closely linked together through their food chains as well as in some of the other ways I have described in this Chapter. Refer to Fig. 160 for some of the food chains in ponds.

An understanding of food chains is most important, for they bring out clearly that the food supply of all animals (and hence of man himself) finally depends on green plants. That is the meaning of the Biblical statement: "All flesh is grass". From this you will realise that agriculture is the human activity upon which man's food supply depends. Farmers and farm workers are the most important people in the world, though usually their work is carried on quietly and without publicity, and they are not as a rule "celebrities" as are film-stars and politicians.

CHAPTER TWENTY-NINE

How Animals and Plants Pass the Winter

WINTER is a season in which the majority of plants and animals find it difficult to live a normal active life. One reason for this is the low temperature, frequently well below freezing point. Birds and mammals are warm blooded, i.e., they keep their body temperature more or less constant. The body temperatures of other animals, and all plants, are usually the same, or nearly the same, as their surroundings, and this complicates the lives of these organisms, for sometimes their body temperature is high and sometimes it is low. In the case of animals, when the body temperature becomes low, activity is much reduced and, before freezing point is reached, they usually become motionless. Flies, for instance, are very active on hot days but in the colder weather of autumn they become sluggish and are sometimes unable to fly at all. It is a general rule that the higher the temperature the more active a cold-blooded animal becomes, always with the proviso that the temperature shall not be so high that it kills the animal.

A simple experiment to show this may be performed with a supply of fly maggots which can be obtained from fishing tackle dealers or by exposing a piece of meat to become fly-blown. Divide the maggots into two lots in small tins. Stand one tin in the coldest water you can obtain (or better, if you can, place it in a refrigerator), and stand the other in warm, but not too hot, water. After a few minutes you will see that the maggots in the warmed tin are considerably more active than those in the cooled tin.

Low temperature will not allow plant growth to take place to any extent, and frost may cause the formation of ice inside the plant's tissues with fatal results. Of course, some plants can stand lower temperatures than others: geraniums and potatoes are easily killed, whereas winter cabbages and pine trees are much more resistant.

Animals and plants can be divided roughly into four groups according to the manner in which they pass the winter. The groups are:—

(1) Organisms that make no change.
(2) Organisms that become inactive, or hibernate.
(3) Organisms that pass the winter in the form of eggs, seeds, or other resting stages (e.g., as pupæ in insects).
(4) Organisms that avoid the winter by migrating to warmer countries.

(1) No Change. In this group are such animals as the rabbit, fox, and weasel. They carry on active life as best they can. Rabbits may, during prolonged hard weather, find it difficult to obtain food, for as a rule they will not eat frosted greenstuff; and, if they do, it makes them ill. However, rabbits in autumn are fat as a result of the food they have consumed in the summer, and usually manage to survive till the spring in spite of the fact that the food value of winter greenstuff is low. During bad weather they "lie up" in their burrows. Foxes, which prey upon other animals—such as rabbits, frogs, beetles, young birds, mice—find these foods more difficult to get. Frogs are not to be found, nor are young birds. Beetles are scarce, and rabbits less numerous than during the later summer (because many of them will already have been killed, and those left will have ceased to breed. Also, the rabbits left alive will in general be the most wary, since the incautious ones will usually be the first to be caught by foxes, hawks, and owls. The various mice either sleep through the winter or remain hidden during cold weather and only go afield on mild days. It is this scarcity of food that makes foxes more daring in winter, when they skulk around human dwellings in the hope of finding a stray duck, fowl, or lamb.

Birds that stay in England during the winter—robins, sparrows, blue tits, and blackbirds for instance, also find it a problem to obtain food, and this makes them bolder than usual. A bird table supplied with scraps will soon attract numerous visitors. Even the bones my dog leaves in the garden are visited regularly in winter by blue tits and sparrows.

Birds do not seem to suffer unduly from the cold, as their feathers provide a blanket of air which, being a very bad conductor of heat, does not allow much warmth to escape. During very cold weather a bird fluffs its feathers so that it looks much fatter than usual. The effect is to increase the thickness of the blanket of trapped air. However, a spell of frost is quite a serious matter for birds, partly because then they cannot obtain a drink, and partly because such food as they may find is firmly frozen to the ground and cannot be detached by their beaks.

In winter, insects are scarce, though some pupæ are to be found. Certain kinds of fruit are still available for birds long after the leaves have fallen from the trees. As I write these words (on Christmas Day), a starling is pecking at an apple still on the tree in my garden, and blackbirds have been busy eating rotting fruit under the tree. But, when the first frost sets in these will be too hard to be eaten. By Christmas, seeds are becoming scarce.

In the rivers and ponds few creatures are left swimming actively. Such fishes as roach, perch, dace, chub, and pike, remain active throughout the winter, but retire to the deeper holes in rivers and always seem to be hungry. At least it is common angling experience that, if one can find the holes where they are lying, there is usually no difficulty in catching these fishes in winter—a very different proposition from the summer months.

In the plant world, the evergreen trees, holly, pine, yew and conifers generally, show little change, though they do not grow. The main danger to these trees is that accumulations of snow may load down and break their branches.

(2) Hibernation. Many animals and plants go into a state of more or less complete rest during winter. During this period of hibernation the living processes of the animal or plant are slowed down considerably so that little of their body food reserves is used. Very many of the cold-blooded animals hibernate, and so do some of the warm-blooded mammals, though no bird hibernates.

Among insects, hibernation of the adult is quite common. Certain mosquitoes hibernate in corners in cellars, and the Small Tortoiseshell Butterfly in an outhouse or garden shed; while the Great Diving Beetle buries itself in the mud at the bottom of the pond in which it lives, and remains there until the next spring.

In bumble bees and wasps it is only the young queens that hibernate; the rest of the colony dies out. In early autumn young queen bumble bees may be seen on grassy banks seeking for suitable holes where they may safely pass the winter. Banks are probably favoured because there is little likelihood that the soil there will become waterlogged, although, of course, the soil does become much wetter everywhere in winter. Queen wasps hibernate in a variety of places. Very often you may find them clinging to pieces of wood inside the garden woodpile, or behind boxes and similar objects in the garden shed. They take a hold with their jaws, tuck their legs and wings underneath their bodies, and hang motionless until revived by the warmer days of spring. In hive bees only the workers and queen survive the winter. The drones are killed by the workers in the autumn. When the cold days finally come, the bees inside the hive gather together into a tight cluster near to the top of the combs and stay thus until spring. They are not asleep and eat a considerable amount of honey, but in this way they contrive to keep themselves warm.

Many fishes (carp, bream, and tench) bury themselves in the mud at the bottom of the water and remain there quite inactive. It is said that frogs also bury themselves in the mud at the bottom of ponds. I myself have found hibernating frogs securely hidden under piles of garden refuse, and others actually buried in the garden soil. One winter I counted twenty-four frogs in the ooze at the bottom of a barrel sunken in the garden. The barrel had been used for making liquid manure the previous summer. Newts and snakes find some sheltered spot (e.g., under logs or in holes at the bases of trees), but some newt larvæ remain in the water throughout the winter.

Garden snails creep behind stones or other objects and attach themselves by means of a gummy material. They then make a thin membrane (the *epiphragm*) across the mouth of the shell and remain thus until spring. You can easily watch the formation of an epiphragm by putting a Garden Snail into a jam-pot and covering the mouth of the pot. In a few days the snail will become fastened to the glass wall and you will be able to see the epiphragm. Some snails bury themselves in the ground during winter and then the mouth of the shell

always faces upwards. Very often, as the weather becomes colder a snail withdraws further into its shell and a new epiphragm is formed underneath the first. A third and fourth epiphragm may sometimes be added. Slugs, like snails, creep into some sheltered spot, but they form no special protection. Often they bury themselves in loose soil.

Among the British warm-blooded animals, hedgehogs, badgers, bats, and many of the "mice" hibernate, or at least sleep for long periods during the cold weather. During hibernation they do not keep their body temperature constant but allow it to fall to that of the surrounding air. Red Squirrels form nests or "dreys" in trees, often using the old nests of woodpigeons, and other birds as foundations. During warm spells the squirrels may become active and feed on stores of food they have hidden during autumn. Grey Squirrels do not hibernate at all and the difficulty of obtaining food in winter is probably an important factor in keeping down their numbers.

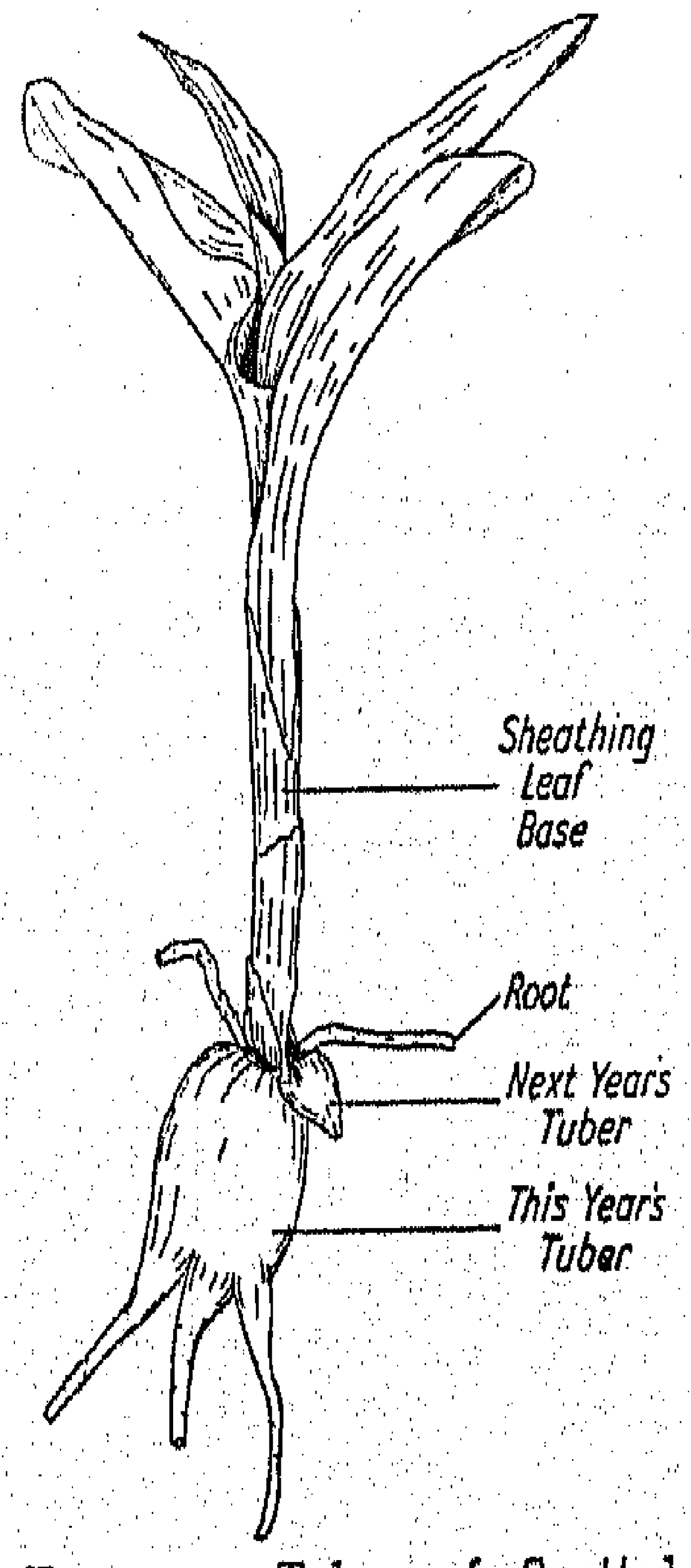


Fig. 173.—Tuber of Spotted Orchis, ×½.

Badgers retire to their underground chambers or "sets" and there lie in a snug retreat lined with dry leaf mould. The badgers waken at intervals for short periods of activity. In spring the bedding is changed—a kind of spring cleaning!

Hedgehogs hibernate in cosy beds hollowed out in moss or leaves, sometimes in old wasp nests. They do not often waken before April.

Rather similar to the hibernation of animals is the state in which perennial herbs pass the winter. In many of these plants the overground parts die away, sometimes entirely or sometimes (buttercups and dandelions) leaving a few leaves at the surface of the soil. Underground, however, there is always some living structure called the "stock". This may be an underground stem, a swollen bud (bulb) or a swollen root, but whatever its nature the stock is always full of some kind of food material which serves to enable the plant to grow again next year. The rhizome of the iris, the corm of the crocus, and the tuber of the potato are good examples of underground stems. The fact that they are stems can be inferred from the presence of buds and reduced leaves. Tulips, daffodils and bluebells provide excellent examples of underground buds. Orchid (Fig. 173) and dahlia tubers are swollen roots, other examples of which are provided by Lesser Celandine tubers and rhubarb "crowns". These swollen roots have, of course, one or more buds from which growth of the overground parts starts again the following year.

The various species of duckweed have a curious but most successful method of wintering. As the water grows cold in autumn, the duckweed fronds become heavier by the formation of much starch within their cells, until they are so heavy that the fronds no longer float but sink to the bottom of the water, where they remain until April or early May of the next year. Then they become lighter again and float to the surface. This curious behaviour is easy to verify by keeping some Lesser Duckweed in a jam-pot out of doors. During October and November the plants will gradually sink. You must not leave the pots outside after this or the water may freeze solid and break the pots. Indoors, the plants come to the surface again in March.

(3) EGGS, PUPÆ, SEEDS. One may search in vain for specimens of *Hydra* during the winter months because the active *Hydras* usually die in cold weather. However, before they die they produce eggs which, after being fertilised by sperms, produce a hard case around themselves and sink to the bottom. There they remain until conditions are again favourable when they develop into new *Hydras*.

Some of the small crustaceans (see p. 192) that dwell in fresh water (e.g., water fleas) also produce special resting eggs in the autumn instead of normal eggs that would hatch at once. These resting eggs remain in the pond until the following spring, when they develop into new animals. In water fleas (*Daphnia*) the females carrying the resting winter eggs inside them are much darker in colour than normal females, and should be sought in the autumn.

Similar resting eggs are produced by other small crustaceans in summer, when the ponds in which they are living dry up. The resting eggs may then be blown about by the wind, a fact which accounts for the appearance of small crustaceans in almost any temporary pool of water.

A number of insects pass the winter as eggs. The Winter Moth (Plate IV) lays eggs on the shoots of apple and other tree in November, December and sometimes January. The eggs remain thus until the warmer days of March and April, when they hatch into caterpillars that feed on the apple foliage. Green-flies also pass the winter as eggs, although it is probable that, in some species of aphids, adults also succeed in surviving. You will remember (see p. 162) that aphids do not normally lay eggs but give birth to young aphids. The aphids which hatch in spring from the winter eggs give birth to young in the normal way.

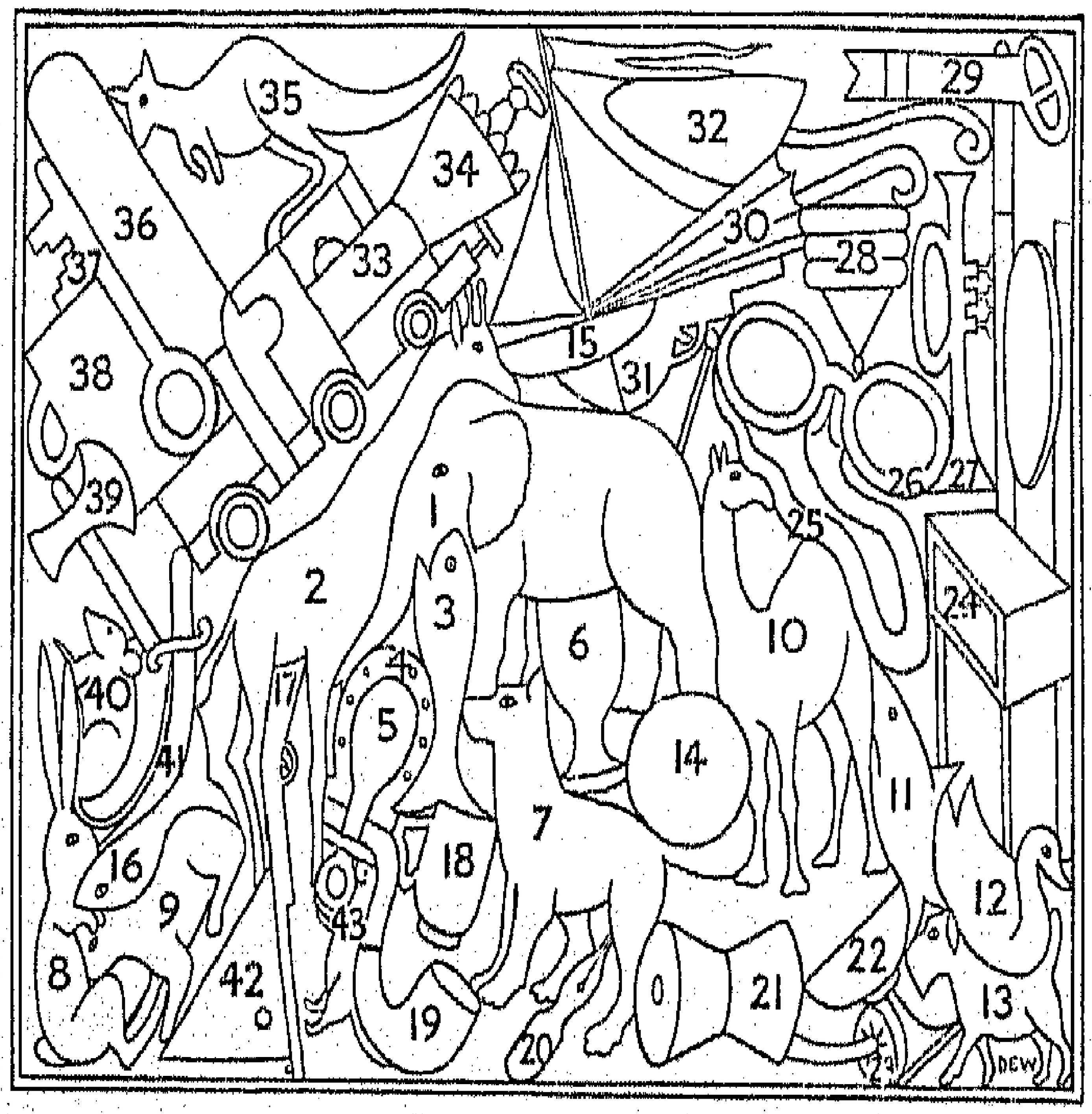
Many insects pass the winter not as eggs but as larvæ or, more often, as pupæ. You will frequently dig up caterpillars of the Cabbage Moth that have passed the winter buried in the soil, and the wireworm—the larva—is the only form in which click beetles pass the winter. Adult click beetles all die in autumn. Most butterflies and moths survive the winter in the pupal state, though we have already seen that some do so as eggs and others as hibernating adults. Dragonflies, and many other insects whose larvæ live in water while the adults live on land, pass the winter only as larvæ, the adults all dying.

Annual plants die in the autumn, but, before they die, seeds are produced and scattered. As a rule these seeds do not germinate until the next spring when the ground becomes warmer. Thus, these plants survive winter only as seeds. Biennials and perennials may also sow seeds that do not germinate until spring, though often the seeds of these plants (e.g., primulas) germinate at once and the young plants are able to withstand the winter.

(4) MIGRANTS. Many birds, especially those whose main food is composed of insects, leave the British Isles in autumn and fly south to warmer lands where food is more easily available. This habit of migrating has been dealt with in Chapter 21. There is a good deal of movement of birds within the British Isles themselves. Many birds frequent the neighbourhood of

houses in the coldest part of winter, presumably because they find food easier to obtain there than in the open country. Other birds flock on to the salt marshes around the coasts, as these are less frequently frozen than other feeding grounds.

KEY TO THE FAMILIAR OBJECTS IN FIG. 119.



1. Elephant.
2. Giraffe.
3. Fish.
4. Horse-shoe.
5. Dummy.
6. Egg-cup.
7. Dog.
8. Rabbit.
9. Dog.
10. Camel.
11. Fish.
12. Duck.
13. Dog.
14. Ball.
15. Yacht.
16. Fish.
17. Rifle.
18. Cup.
19. Pipe.
20. Nib.
21. Diabolo.
22. Wine-glass.
23. Mushroom.
24. Dressing-table.
25. Snake.
26. Spectacles.
27. Trumpet.
28. Top.
29. Signal.
30. Umbrella.
31. Revolver.
32. Shoe tree.
33. Railway engine.
34. Lamp.
35. Kangaroo.
36. Cricket bat.
37. Key.
38. Can.
39. Axe.
40. Mouse.
41. Sword.
42. Set-square.
43. Cat.

PART IV

CHAPTER THIRTY

Things To Do

IN this section of the book, I am going to suggest a number of things that you can do. There are suggestions for activities you can carry on throughout the year, either alone or in co-operation with friends and these are followed by suggestions for activities at different seasons.

All the year round activities

(1) A NATURE NOTE-BOOK. Whatever else you do, you *must* keep a nature note-book in which to enter observations that you make of natural history events, and in which you should make drawings and paintings of things that appeal to you. Make it a rule to write something in the book each day—a record of the first buttercup seen in flower, the nesting behaviour of birds, the appearance of a fungus on a tree or on the lawn, the discovery of beetles in the body of a dead bird, or anything else of interest. If you are constantly on the alert. you will find much to record, even in towns. For instance, a boy I know noticed that, when the lime trees in Coventry shed their leaves in autumn, it nearly always happens that the last leaves to fall are the ones right at the ends of the branches.

Here is a page from my own note-book, to illustrate my meaning.

March 20th, 1947.	Hazel catkins out, and the female flowers showing their red stigmas. They are late this year.
March 23rd.	A single Ladybird beetle and several ground beetles were active to-day in the garden. I noted that crocus flowers close in the daytime when the temperature is low.

March 31st.	In Corley Wood I came across a Rowan Tree (Mountain Ash) the base of whose trunk had been severely nibbled by rabbits. All the bark over an area of about 100 sq. inches had been nibbled away to the wood. There were signs also that bluebells had been nibbled some time earlier. Is this the result of food shortage due to the hard winter? I believe rabbits do not much care for bluebells.
April 1st.	In Corley Wood I found a female earwig with forty-two eggs in a neat cluster under the bark of a dead stump. The eggs were pale yellow in colour, oval in shape.
April 5th to April 12th.	The rooks are building in Shropshire. To-day I watched one stealing sticks from another's nest, but only in the absence of the owners. The rooks came to the walnut tree in the garden and broke off twigs for use. I could not see whether the twigs were live or dead wood, but in either case the strength of a rook's beak must be considerable.
April 10th.	The Cuckoo is reported in the daily press as having been heard at Dulwich.
April 16th.	An Earthworm (*Lumbricus terrestris*) was killing itself in a curious manner. The head end had started to go down the same burrow as that in which its tail was lying, and had become stuck. The result was that a loop of the middle part of the worm was left on the lawn and had dried up in the sun, because the worm could neither go down the burrow nor withdraw from it. As far as I can tell, the only worms that lie out at night on my lawn are specimens of *L. terrestris.* Wood anemones close at night, as do crocuses.
April 17th.	Hive bees are working the Wych Elm for pollen, though this should be a wind-pollinated plant to judge by the structure of its flowers.
April 19th.	I heard my first cuckoo at Baginton. This is nine days after the first one recorded in S. England. Early Humble Bees are working the daffodils.

(2) COLLECTIONS. Make collections of some groups of plants or animals, following the instructions given at various places in the text. I suggest you undertake one or more of the following:

(*a*) Collect the plants found commonly growing in some definite type of place, such as:

- (i) An oak wood
- (ii) A meadow, or ordinary pastureland
- (iii) Waste ground, commons, or heaths
- (iv) Hedgerows and ditches
- (v) On the stone walls so common in certain parts of Britain
- (vi) In the soil-filled cracks where pavements and pathways join walls, in between bricks in yards, and similar places.

(*b*) Make a collection of dry fruits and seeds. Each type of fruit could be kept separately, glued on to a slip of white cardboard in the tray of an empty matchbox. You might concentrate on one or more of the following types:

- (i) Fruits and seeds that are distributed by the wind. These would include the parachute types such as dandelion fruits and willow herb seeds, and the gliders such as sycamore, elm, lime, and ash fruits, and pine and birch seeds.
- (ii) Fruits and seeds which are dispersed by clinging on to animals by hooks. They include burrs, the fruit of burr marigold, goosegrass, agrimony, geums, and many others.
- (iii) The fruit of those plants that arrange for their own dispersal, either by having explosive fruit (gorse and broom), by squirting them out (e.g., violets), or by shaking them out when the stems are blown by the wind (e.g., poppies, snapdragons, bluebells, and delphiniums).

(*c*) Snail shells. If you collect snail shells, both land and fresh water, you will soon become aware that snails are quite particular in regard to their habitats. You will not find many in pine woods, nor in fast flowing streams. If you live in chalk country, you will find many more types than if you live in an area where the soil is sandy or clayey in nature. The crevices in the bark of tree trunks are often found to yield some of the smaller kinds of snails.

Snail shells may be kept on cotton wool in shallow tins (two-oz. tobacco tins are suitable), or they may be mounted with glue on white cardboard. In either case the date and place of capture, together with the name of the shell, if known, should be recorded. Before mounting a shell one should remove the living contents. Kill the snail by dropping it into boiling water and then extract the dead body by means of a pin bent into a hook at the point. For the larger snails it is perhaps best to drown them in warm water (see p. 74) and then pull out the body by means of a loop of coarse string tied round the exposed part.

Slugs are not easy to keep in amateur collections, but many of them have delicate flattened white shells hidden inside the rear end of their mantles. These shells are easily obtained with the aid of a sharp pair of scissors and a needle, and may be mounted on cardboard blackened with Indian ink.

(*d*) Beetles are a most interesting group to collect. You may decide either to collect beetles in general or those from some particular habitat such as water; or from fungi (nearly every fungus has one or more beetles associated with it—I obtained two species from the bracket fungus shown in Plate I); from the corpses of dead animals; from inside rotten wood; or from any of the habitats listed under (1).

Unfortunately, many of the smaller beetles are not easy to name, even with the aid of a good key. Nevertheless, you will soon get an idea of the main types, and some of the larger beetles are quite easy to recognise from pictures.

(3) A JAM-POT ZOO. A jam-pot zoo is a most desirable possession. All that is required is a shady spot, preferably protected from rain, where you can keep a dozen or so jam-pots. About half the pots should have their open ends covered with fine cloth held in position by elastic bands or string. The others are to contain pond water with water creatures. Dragonfly larvæ, water beetles, water boatmen, water snails, and certain caddis fly larvæ may all be kept successfully, and various water plants, especially duckweed and Canadian pond weed, will thrive. Cultures of the smaller crustaceans (*Daphnia* and *Cyclops*) may easily be obtained by leaving leaves to rot in pond water. These smaller creatures can be used to feed cultures of *Hydra*. Try to obtain both green and brown *Hydras*, and the various kinds of duckweed (see p. 36).

Bright sunlight should never be allowed to fall on creatures in jam-pots—it will almost certainly kill them. Generally speaking, the jam-pot zoo is better kept out of doors, except in the coldest part of the year. The inhabitants of your zoo will naturally change as the year goes on.

(4) GARDEN WEEDS. On one particular day each month make a list of all the various weeds in your garden. Make a note whether the weeds are in flower, fruit, or only in leaf. Note also against each kind of weed whether it is abundant, common, or scarce, and, where necessary, make a note of gardening operations that may have had an influence on the weed population. The results may well be set out in a table. Here is a survey of some of the weeds in my garden in August.

PLANT	STAGE	NUMBER PRESENT
Groundsel	Flower and fruit	Abundant
Rosebay Willowherb	Flower and fruit	Common
Greater Celandine	Fruit	Scarce
Poa Annua	Flower and fruit	Abundant
Dandelion	Leaf	Scarce
Sun Spurge	Flower and fruit	One specimen
Broadleaved Willowherb	Flower and fruit	Scarce
Enchanter's Nightshade	Fruit	Scarce
Convolvulus	Fruit	Common in one place
Foxglove	Leaf	One specimen under hedge

If you can arrange to exchange lists with friends in other parts of the country, or even of your town, you will soon discover that some of the weeds are common in nearly all gardens, while others grow only in certain areas.

(5) A Study of the Life History of One Plant. Make a close study of the life history of one plant. Any plant will serve, but it will be an advantage to choose one of the weeds in the garden, or a plant that grows commonly near your home.

The types of things to study and notice are:—

(*a*) Is your chosen plant an annual, biennial, or a perennial? You can decide this only by watching particular plants for more than two years.

(*b*) Make drawings of the plant's general habit (i.e., its shape and manner of growth); of its leaves, buds and stems; of any underground stems that are present, and of its rooting system. *Draw actual specimens.*

(*c*) Study the plant's relation with insects, e.g., which insects visit its flowers? Is it infested with aphides, or frog hoppers (the insects that make the frothy "cuckoo-spit"), or ants, beetles, or caterpillars? Are galls ever found on it, and if so what causes them? To decide these questions you will probably have to study a number of different specimens of your selected plant.

(*d*) Where does the plant normally grow, e.g., in full sunlight or in shade; in dry or damp places; in the open or in the shelter of other plants such as in the centre of a hedgerow?

(*e*) Study the nature of the fruit. How many seeds, on the average, are produced from each flower? This will involve counting the seeds from a number of fruits. Then find out the manner in which the seeds are dispersed, and how many seeds out of 100 chosen at random actually germinate (see Fig. 131).

Finally, study the structure and germination of the seeds—whether they are epigeal (i.e., their cotyledons come above ground, Fig. 130), or hypogeal (i.e., their cotyledons remain below ground. Grow some out of doors and see whether they are attacked by slugs, woodlice, birds, and other enemies of seedlings.

Make careful drawings of the various items, with the aid of a hand lens if necessary, and keep careful records, so that, when you have completed your study, you will have a little booklet all about one plant.

(6) Colour. At all times be on the lookout for examples of warning and protective coloration in animals (see Ch. 22). Winter is the time of greatest danger for most animals because then there are fewer hiding places, and food is in short supply. This food shortage causes many animals to take risks they would not take in times of plenty, hence it is especially in winter that most animals need to be inconspicuous, and you will find that the colours of many common birds—sparrows, blackbirds, and thrushes for example—harmonise very well with the bare branches and trunks of trees, or with the browns and blacks of a winter landscape. It is when a bird is resting, or feeding on the ground, that it has the greatest need of protective coloration.

At other times of the year you will find much to think about in the colours of moths, fishes, snails, grasshoppers, frogs, and snakes.

(7) A Group Activity. With other members of your natural history society, you might prepare a large map of your district and insert such facts of biological interest as the following: which ponds are used by toads, frogs and newts for breeding; which particular kinds of newts are to be found in particular ponds; the species of duckweed on each pond; the sites of the rookeries (if any) in your area; the places where sand martins live; where particular kinds of plants are to be found; what kinds of fishes are present in the various ponds and streams (information may usually be obtained from anglers), and other topics of interest. In towns, maps showing the kinds of trees planted in the streets and parks, are interesting. Any trees attacked by bracket fungi or galls could be specially indicated.

Seasonal Activities

Here are a few suggestions for things to do, mostly out of doors, at particular times of the year. You will find other suggestions scattered throughout the text of this book, and in some of the books in the list beginning on p. 323.

(1) DECEMBER, JANUARY AND FEBRUARY

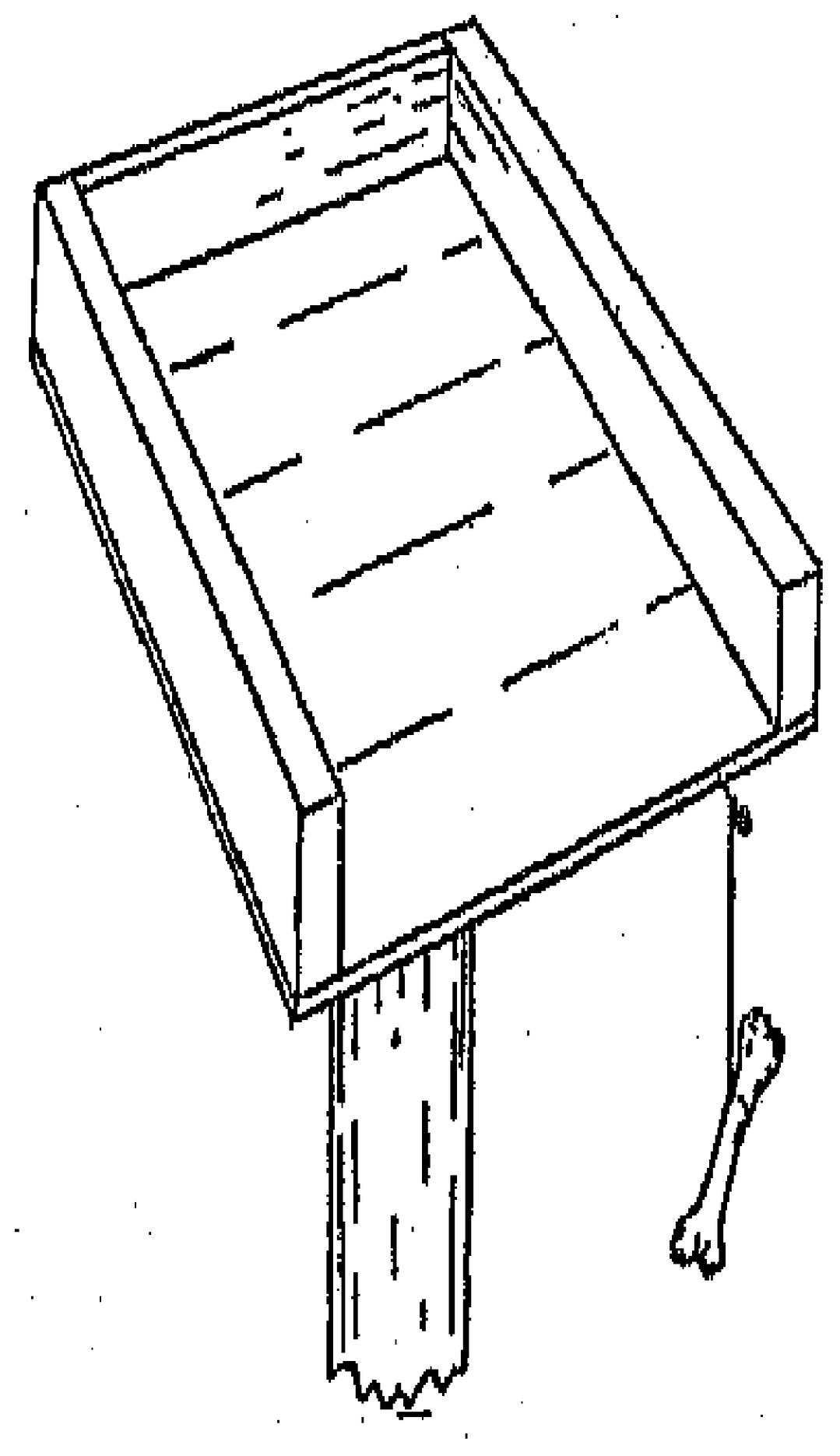


FIG. 174.—A bird table made from a seed box.

(*a*) Construct a bird table where you can easily see it from the house. Do not have it too close to a window, but about ten yards away. My own bird table is made from an old seed box with one side removed (Fig. 174). The removal of the side makes it easy to brush away fish bones and other things the birds do not eat. Provision the table regularly with scraps of food, and you will soon have a variety of birds attending. Try to identify your visitors from the coloured illustrations in a good bird book such as *Birds of the Wayside and Woodland* (see p. 326). Make a list of the winter visitors you identify, and also observe how many more birds visit your table during spells of severe frost.

(*b*) Construct one or more nesting boxes for tits. The boxes may be made out of ordinary packing case wood—the thicker the better. The hole should be the size of a two-shilling piece for Blue Tits, and of half a crown for Great Tits.

Fix the boxes about five feet from the ground in shady situations on the trunks of trees or in other suitable places. Make sure that cats will not be able to interfere with them. Usually tits begin nesting in April.

(*c*) Combine with friends to plot the distribution of rookeries in a chosen area—say a radius of two to three miles around your house. In a country area, you may need to consult farmers, gamekeepers, the postman, and other such persons, for information, but vigilant observation from roads will give you much. A one inch Ordnance Survey map will be a great help, because it shows the situations of woods and plantations. Try to form some idea of the number of nests in each rookery, and mark this on the map (say one dot for three nests), together with the kinds of trees in which the nests are built.

(*d*) Make a study of the winter twigs of common trees. The excellent little pamphlet *How to Identify Trees and Shrubs from Leaves or Twigs* (see p. 324), will assist you to identify any kind of British tree from its twigs. Make drawings of the twigs of the common trees, and add notes about the colour and nature of the buds, the shape of the tree, and the nature of the bark on the trunk. Practise recognising common trees from a distance by their general outline against the sky.

Towards the end of this period, take several twigs indoors and place them in water. At short intervals make drawings of selected specimens as the buds burst and the leaves unfold. This may take place a week or two before the trees out of doors come into leaf.

(*e*) In December and January search on the trunks of apple trees for female Winter Moths climbing to lay eggs on the buds (Plate IV). If trees have been grease-banded, you may find several of the moths caught on the sticky band. If you are fortunate enough to obtain a Winter Moth place her in a jam-pot with a few fresh apple twigs and she will almost certainly lay thirty to forty pale bluish-green eggs.

(*f*) Make a study of the problem "How do animals pass the winter?". Search among piles of rubbish and heaps of moss, and under rotting logs and large stones, to find such creatures as snails, woodlice, spiders, and beetles. Occasionally, newts and frogs may be found. Split open the hollow stems of plants that have died down (such as delphiniums and lupins) and see whether there are insects hiding inside them. During suitable weather see what you can find with a net in ponds. On walks, look out for grey squirrels, rabbits, hares, and other creatures, and during warm spells note what insects are active.

(*g*) Keep a look out for such plants as may be flowering. *Poa annua* (p. 30), hazel, shepherd's purse, groundsel, dandelions, early primroses and crocuses, and the ornamental shrub Daphne may all be found, though the actual time in any particular year will depend on the weather.

(2) MARCH, APRIL AND MAY

(*a*) As soon as the ground is in fit condition, plant a few shallots and half a dozen potatoes in a place where they may be dug up as required. The shallots are simply pressed into the firm ground, so that about half the bulb is underground.

They have a tendency to push themselves out of the soil, or to be pulled up by birds, and may require replanting once or twice. Dig one up after a fortnight, and others, at intervals of a month, until August. Examine and make drawings of each stage and by the end of this period you will have a good idea of vegetative reproduction in the shallot.

The potatoes should be planted in a row, the tubers being placed about a foot apart and four to five inches deep. Keep two more potatoes indoors in the light, so that you may observe the early stages in the formation of shoots. Each month dig up a potato from the soil, and, during the earlier stages, make drawings of the complete plant. Later on, draw only sufficient to show the formation of the new potatoes at the tips of the underground stems.

(*b*) Identify, and make a collection of, the insects visiting the spring flowers in your garden.

(*c*) Plant in pots of soil some of the seeds or fruit of trees that you collected in autumn, and tend them until they grow into small trees. Suitable ones are acorns, "conkers", sycamore fruit, and apple pips. Date stones will sometimes grow into little date palms. Make drawings of the early stages and note whether a particular tree seedling is epigeal or hypogeal (see p. 310). In the case of an epigeal seedling such as sycamore, try the effect of cutting away the cotyledons shortly after they appear above ground.

(*d*) You can perform an instructive experiment on daffodils to find out whether pollination is necessary before the ovary can produce seeds. Choose four healthy daffodils growing outside, and obtain two waxed paper bags—the waxed containers in which corn flakes are packed are very suitable. To commence the experiment wait until the buds of the daffodils are just beginning to burst, when the tips of the yellow petals are just visible. Leave two of the daffodils alone, but open the petals of the other two and carefully remove the stamens, trying to avoid letting the anthers touch the stigmas. It does not matter about tearing the petals. At this time the anthers of the stamens should not have burst and there should be no pollen about. Place the head of each daffodil, from which the stamens have been removed, inside one of the waxed paper bags, and fasten the mouths of the bags round the stems below the flowers with pieces of string. The purpose of these bags is to prevent insects gaining access to the flowers and perhaps bringing pollen.

When the stamens in the two untouched daffodil flowers are shedding pollen freely take a paint brush and dust it well in this pollen. Then remove the paper bag from one of the two daffodils with no stamens and rub the pollen-covered brush several times on the stigma of this flower. Next replace the bag.

Leave all the flowers to wither. When the ovaries of the two untreated flowers are swollen and full of seeds, remove the paper bags from the two flowers whose stamens were removed. You should find that the ovary of the one that was dusted with pollen is firm and swollen, and contains many seeds, while the ovary of the other, whose stigma received no pollen, is shrivelled and contains no seeds. The only difference in treatment between these two flowers was that one, which produced seeds, had its stigma dusted with pollen, whereas the other, which produced no seeds, received no pollen. Hence it is reasonable to suppose that the pollination was necessary before seeds could be produced. The two untreated flowers were pollinated by insect visitors. In order to make quite sure of these conclusions, the experiment ought to be performed on very many plants. However, most people will be loth to use all the daffodils in their gardens for this purpose, and, if several friends perform the experiment separately, the combined results may be taken as convincing. The stamens are more easily removed in tulips, but tulips sometimes fail to produce seeds, even when pollinated.

(*e*) Search in ponds with a net for dragonfly larvæ. When you have obtained some, place them singly in jam-pot aquaria and feed them on small water creatures or on tiny pieces of raw meat tied to pieces of cotton. *Do not leave meat in the water*, or the water will become foul.

Place a twig in each jam-pot for the larva to crawl up when it is ready to turn into a dragonfly. Some dragonflies, especially if ill fed, require two years in the larval stage.

At this time collect and keep other aquatic creatures.

(*f*) Frog spawn is available towards the middle of March. Take a *little* and rear the tadpoles in a jam-pot of pond water. Feed them on water weeds at first, afterwards feed some on raw meat (e.g., chopped worms) and others on raw carrot. If the tadpoles are too crowded, they will eat one another.

You may also be able to catch newts in ponds about this time. If you have not a glass aquarium, place several males and females in a bucket of pond water together with some water weed. Feed them on small worms, small water creatures, or fly maggots. They will almost certainly lay eggs which will hatch into newt tadpoles (see p. 68). About June the adults will leave the water to spend the rest of the year on land, but many of the larvæ will remain in the water until next year. The larvæ may be transferred to jam-pots where they will be more easy to observe. They will feed on small crustaceans and other tiny pond creatures, such as are likely to be present in freshly-gathered water weed.

Water weed (especially duckweed) should be kept in each jam-pot aquarium because green plants help to oxygenate the water, and the floating duckweed provides a pleasant screen from bright light falling from above.

(*g*) Search in May for the young male and female cones of cypress, *Thuya*, and pine.

(*h*) Towards May examine oak trees for galls, especially the Currant Galls (p. 285) present on the male catkins. The catkins are present only for a short time. The insects from many galls will hatch out if the galls are kept in tins or jam-pots, but sometimes the galls shrivel and dry up if they are too young when gathered.

(*i*) In April, queen wasps are frequently to be seen, often in a drowsy condition when they may easily be caught.

(3) JUNE, JULY AND AUGUST

This period is the one that has the most to offer to the keen naturalist. Insects, birds, and flowers, are especially numerous

(*a*) Undertake a study of the manner in which the corpses of birds and other animals are disposed of in nature. The simplest way is to place fowls' heads, or dead mice and rats, in the garden, protecting them from cats with wire netting, and to examine them at regular intervals. Various beetles will be obtained, as well as the maggots of several kinds of two-winged flies. The large Sexton Beetles may sometimes visit a corpse and bury it.

Samples of the maggots living in the corpses should be taken from time to time and kept in tins with soil until they pupate. Ultimately the flies will hatch out, and often they will be mixed with smaller insects which have been parasites on some of the maggots.

Whenever you come across a dead animal, always examine it to see what creatures are feeding on it. Most will be underneath.

(*b*) Find a young tender shoot of a rose bush that has no greenflies upon it, and place it inside a specimen tube fitted with a cork. Transfer to it one of the fat greenflies that is walking about (i.e., not feeding with its proboscis embedded in the plant's tissues) elsewhere on the rose bush. The insect can easily be picked up on the point of a moistened paint brush. Examine the twig at intervals for about a week, counting the number of greenflies present each day. This will give you an idea of the rate at which greenflies reproduce. If you watch the original greenfly from time to time through a hand lens, you may, with patience, actually see a young greenfly born. Greenflies lay eggs only towards the end of autumn.

(*c*) Find a plant heavily infected with aphides and over-run with ants. Watch a particular group of aphides through a hand lens and you should see the production of droplets of honeydew by the aphides. The honeydew is kicked away as it is formed (see p. 292). Sometimes you may see an ant approach an aphis and stroke it with its antennæ. The aphis may then produce a droplet of honeydew and leave it to be sucked eagerly by the ant. Do not be impatient should you not see these events immediately, for they certainly do happen.

(*d*) Make a collection of the bumble bees and cuckoo bees of your area and take note of the flowers they visit. Note also as many as possible of the flowers visited by one bee on a particular journey. Are all those flowers of one kind? Examine a load of pollen from the hind leg of a bumble bee. Is it all of one kind? Try to find out those flowers that never seem to be visited by bees. Does their structure agree with what is written on p. 237?

(*e*) Catch every wasp that enters your house throughout the summer, and find its species. Keep a record of the numbers of the various kinds. You will probably obtain only two or three species.

(*f*) Take an ordinary garden snail and place it in a jam-pot. Cover the mouth of the pot with paper or cloth and leave it. In a day or so the snail will become fixed to the wall and will produce a delicate membrane—the epiphragm (see p. 76)—across the mouth of its shell. This can be easily observed through the glass wall of the jam-pot. Alternatively, if the snail is left undisturbed, it will remain in the same place for a very long time. One such snail (that drawn in Fig. 41) which escaped from a box in my dining-room attached itself to the underside of the mantelpiece and was still alive a year later. If these resting snails are sprayed with water, they normally become active again in a few minutes.

(*g*) Towards the end of June, mosquito larvæ should be present in patches of standing water, in rain barrels and exposed water tanks. Try to obtain larvæ of both *Culex* and *Anopheles* (see p. 158). They are easily reared to the adult form in jam-pots containing pond water, and, if sufficient are kept, you should see one or more adults actually emerge from the pupal case (see Fig. 84*b*).

Place one or two larvæ and pupæ in a small tube about half filled with water and try the effect of adding a drop of paraffin to the surface. Malarial fever is carried from man to man by mosquitoes, and frequently in countries where it is prevalent, the mosquito larvæ are destroyed by spraying paraffin on to water containing them.

The paraffin film probably acts in two ways, (1) it "wets" the inside of the breathing tubes and invades the tracheal system, and (2) impurities present in it poison the larvæ.

(*h*) Collect bunches of water weed from several places and put them in jam-pots with pond water. Examine the walls after a day or so and on some of them you should find a number of *Hydra*, either green or brownish-white in colour. By feeding them with *Cyclops* and small *Daphnia* you can cause the *Hydra* to grow rapidly and produce buds which will soon separate from the parents as young *Hydra*. With a hand lens see if you can determine whether the buds have always the same number of tentacles as the parent.

Take a *Hydra* from a jam-pot with your pipette (Fig. 58*c*) and place it upon a plate. Cut it across into two parts with a razor blade and place both parts in a clean tube with a little pond water and leave it alone for a few days. You will then probably find that both parts have grown into complete *Hydras*—the part that had no tentacles having grown a new set. This process of growing missing parts is called *regeneration*. In human beings the power of regeneration is slight, being limited to such minor events as the growth of new skin over a wound.

(*i*) Make a study of the "guide lines" on flowers (see p. 232). Find out flowers that have guide lines running to the nectaries; search for any that have "guide lines" but no nectar; and look for flowers that have nectar but no "guide lines". From the above observations and by watching the behaviour of insects obtaining nectar from flowers, try to form an opinion as to whether "guide lines" are really of any assistance to the insects in their search for nectar.

(*j*) In July, search for colonies of Small Tortoiseshell Butterfly caterpillars on nettles. The caterpillars remain in colonies until they are about half grown. These caterpillars may easily be reared at home.

In late August, or sometimes September, collect caterpillars of the Cabbage White butterflies from cabbages and similar plants, and from garden nasturtiums on which, in most town gardens, they are usually very abundant. Keep a number in a large box until they pupate. You will find that very many of the Large Cabbage White caterpillars fail to do so; instead, twenty or thirty little golden cocoons of the parasitic wasp *Apanteles* will be formed around each dead caterpillar. The wasps will hatch out in due course.

(*k*) July is a good month in which to study the reproduction of the Lesser Duckweed (*Lemna minor*). Take a single healthy frond and, after drawing it, allow it to float upon pond water in a jam-pot kept in the light. Draw it, on the same page, at intervals of three days for several weeks. At the end of this time your drawings should be a record of the way in which new fronds are produced.

Also prepare jam-pots with cultures of as many of the other duckweeds as you may have. These are to be left standing outside in a shady place. (I find that direct sunlight kills the Ivy Leaved and the Greater Duckweeds.) Towards the end of autumn you will find that the plants sink to the bottom of the water and there remain all winter. Next spring they will float to the top again.

(*l*) If you have not yet obtained newt larvæ, search in a pond with a net. The larvæ at this time will be delicate little creatures with four legs and a tuft of three feathery gills on each side of the head.

(*m*) Larvæ of the ladybird beetles are to be found on plants infested with aphides. By watching patiently you should be able to see the larvæ feeding on the aphides. A good plan is to put an aphis infested shoot, together with some ladybird larvæ, in a small tube. Then they may more conveniently be watched through a hand lens. Pupæ of the ladybirds are almost certain to be present somewhere on the plant.

(*n*) Dig out ants' nests on to a sheet of white paper or a white cloth—the ants are unlikely to sting you. You will find various beetles, mostly small ones, present as guests in the nests. Besides the beetles you may find the small white woodlouse mentioned on p. 192.

At this period also keep a lookout for winged ants. These are the kings and queens (males and females) and on certain days they swarm from the nests in great numbers.

(*o*) Continue your studies of galls. Hop Galls, Spangle Galls, and Oak Apples are now to be found on oak trees. Galls on other plants (willows, maples, sycamores, roses, and nettles, for example) are abundant. Try to hatch out the insects from the various galls, but bear in mind that they may not emerge until the following year, and that not all galls are caused by insects.

(*p*) At this time of the year it is profitable to collect in meadows, hedgerows, and similar places, with a sweep net (p. 8). The net is swished about among the herbage with quick firm strokes, and should yield a rich assortment of beetles, spiders, harvestmen, ants, grasshoppers, plant bugs, and similar creatures.

(4) SEPTEMBER, OCTOBER AND NOVEMBER

(*a*) September is the best month to study the Garden Spider. Large females and their webs are usually abundant. Try to obtain a complete web on a sheet of glass as described on p. 186. Try also to deceive a spider by twiddling a piece of grass stalk in the web in imitation of a fly's struggles. Often a spider will rush towards the point of disturbance only to halt and retreat hastily as she discovers the deception.

You may, by throwing live flies into the web, observe the manner in which a spiders deals with prey. As soon as the spider's poison fangs sink into the fly, its struggles cease. The spider, if hungry, will then proceed to suck the juices from the fly, but if the spider is not hungry it will bind the fly in a swathe of silk drawn from the spinnerets. As the silk is drawn out the spider rotates the fly rapidly with its hind legs. Such "wrapped" flies are frequently to be found in webs.

Perform experiments to find out whether a spider is capable of repairing damage to the web.

(*b*) At the end of September plant daffodil or tulip bulbs for the experiment in spring (p. 314).

(*c*) During this period you should make a collection of fruits and seeds, especially of those trees that you may wish to grow in pots (p. 230).

(*d*) Make observations on the eating of fruits and berries by birds. As far as is possible, find out which birds eat particular berries. Search also in the droppings of birds for seeds that have passed through the bird undigested. If you care to do so, it is instructive to spread the droppings of birds (collected with a spoon) in plant pots full of soil that has been baked in the oven to kill any seeds it may have contained. Water the soil regularly. Any plants that now grow will have come from seeds present in the bird droppings.

You may find that certain berries are not eaten at all until the middle of winter. Which are they?

(*e*) This is the best time of the year for collecting fungi. Make a series of spore prints as instructed on p. 52. You may also get an opportunity of finding out whether "toadstools" can withstand frost.

Try to decide whether particular fungi are usually to be found growing near particular trees. To do this, of course, you will have to make frequent visits to woods.

(*f*) Search for the maturing cones of cypress, *Thuya*, and pine. They will be green, as yet, but will presently turn brown and liberate their seeds. (N.B.—Pine cones take three seasons to ripen fully.)

(*g*) Try to grow some prothalli (p. 41) of a fern. The spore cases underneath the fern fronds usually ripen about September. They are then deep rusty-brown in colour. Rub off a number of the spore cases with your fingers and sprinkle them on to a piece of broken plant pot small enough to fit inside the mouth of a 2-lb. jam-pot. The plant pot should be moistened. Now lay it on the ground in a moist shady place with the spore covered side uppermost. Cover it with the inverted jam-pot, pressing the rim of the jam-pot a little way into the soil. Leave it in this position, and in time you should find some small green prothalli growing upon the piece of broken jam-pot. If no fern prothalli appear, it may be because the spores were not ripe or that the situation is too dry.

Another method is to place the piece of broken pot with spores on it at the bottom of a wide mouthed jar fitted with a screw-on lid (e.g., a honey jar) in which one or two *small* holes are punched. Just cover the bottom of the jar with water so that the broken plant pot is kept wet. Screw on the lid of the jar, and keep the jar in a light place, but away from direct sunlight. Do not allow the piece of pot to become dry.

(*h*) Collect a number of fallen acorns and keep them in a tin. You will usually find a number of small white grubs emerge on to the bottom of the tin. These are the larvæ of a beetle—a weevil that lays its eggs in the acorns. Try to rear them to the adult stage.

CHAPTER THIRTY-ONE

Book List

THE following is a selection of some of the books that I have found pleasurable to read or of assistance in identifying specimens. Many that are out of print may be obtained through libraries. If a particular book is not in a public library, it may be obtainable through the National Central Library.

BOOKS PLEASURABLE TO READ

(1) *Life of the Wayside and Woodland.* T. A. Coward. (Warne.)

(2) *A Year with Nature.* J. E. Roberts. (Methuen.)

(3) *Wild Life through the Year.* Morse. (Black.)

(4) *Nature by Day.* A. R. Thompson. (Nicholson and Watson.)

(5) *Nature by Night.* A. R. Thompson. (Nicholson and Watson.)

(6) *Life of the Shore and Shallow Sea.* D. Wilson. (Nicholson and Watson.) Nos. 4, 5, and 6, are fascinating books, excellently printed and lavishly illustrated with splendid photographs.

(7) *The Life of the Spider.* J. H. Fabre. (Hodder and Stoughton.) J. H. Fabre was a very eminent French naturalist of the last century, and has written many books, all of which will create enthusiasm in the young naturalist. Look in the library catalogue for other titles. A simple account of his life has been written by Eleanor Doorly and is called *The Insect Man* (Heinemann).

(8) *How to Study Birds.* S. Smith. (Collins.)

(9) *Birds of the Night.* E. Hosking and C. Newberry. (Collins.) This book is about Owls, and is illustrated with very fine photographs. One of the authors, Eric Hosking, is well known for his photographs of birds.

GENERAL BOOKS FOR IDENTIFICATION PURPOSES

(10) *The Standard Natural History.* Edited by W. P. Pycraft. (Warne.) Deals with all groups of animals, and contains a vast amount of information, but it is not restricted to British types. It is well

worth obtaining, if only to see the 900 or more illustrations and coloured plates.

(11) *The Country Book.* E. Golding. (Ward Locke.) Has chapters to assist with the identification of the commonest members of most groups of plants and animals. In addition there are chapters on simple geology, astronomy, the weather, map reading, architecture, and other topics. Well illustrated with line drawings.

(12) *An Introduction to Zoology through Nature Study.* R. Lulham. (Macmillan.) An excellent book, full of information and ideas for the outdoor naturalist. It deals with all the groups of invertebrate animals present in Britain, but has nothing about vertebrates. Very fully illustrated by line and half-tone. A book to possess, if possible.

(13) *Animal Life in Fresh Water.* H. Mellanby. (Methuen.) A book to assist those interested in the invertebrates present in fresh water to make partial identification of specimens. In most cases it does not take identification down to the species. Illustrated with very clear line drawings.

(14) *A guide to the study of Fresh Water Biology.* J. A. and P. R. Needham. (Comstock Publishing Co., New York.) This book is intended for students of American fresh water life, but the numerous keys (down to genera) and lavish illustrations will be of great help in the identification of the genera of British specimens. The higher plants living in fresh water are omitted.

BOOKS FOR THE STUDY OF PARTICULAR GROUPS

Plants

FLOWERING PLANTS

(15) *A Flower Book for the Pocket.* M. Skene. (Oxford.) Contains coloured illustrations and descriptions of most of our common flowers.

(16) *British Flora.* G. Bonnier. (Dent.) Consists of keys to the British Flora. The keys are illustrated with line drawings, but are not easy for beginners to use, because of the numerous terms which have to be employed. Nevertheless, for those who wish to maintain a life-long interest in wild plants, using a flora is the most desirable method of naming a flower.

TREES

(17) *Identification of Trees and Shrubs.* F. K. Malkins. (Dent.) In addition to the text there are keys. Illustrated with photographs.

(18) *How to Identify Trees and Shrubs from Leaves or Twigs.* C. T. Prime and R. J. Deacock. (Heffer.) This little booklet costs only 1s. 6d. and contains two keys, one for the identification of trees in summer, the other for identification from the twigs in winter. It is illustrated with line drawings of leaves and twigs, and is simple to use.

FERNS

(19) *Wayside and Woodland Ferns.* E. Step. (Warne.) A good popular account of British ferns. It is well illustrated and contains chapters on Horsetails and Club-mosses.

MOSSES

Mosses are a difficult group to study without the aid of a microscope.

(20) *Study of Mosses in the London District.* (School Nature Study Union.) This will be of some help to those living in the London district. Also useful is *Woodland Mosses* (Forestry Commission Booklet No. 1, Stationery Office, 2s.) This contains a short introductory chapter on moss structure, followed by descriptions and photographs of 20 common species of woodland mosses.

FUNGI

(21) *How to identify British Fungi.* J. H. Crabtree. (Epworth Press.) An introduction only.

(22) *The Romance of the Fungus World.* Rolfe and Rolfe (Chapman and Hall). A most stimulating book, but not concerned primarily with identification, although a number of the commoner fungi are illustrated by photographs. Well worth reading.

(23) *British Fungi, with a Chapter on Lichens.* G. Massee. (Routledge.) Useful on account of the excellent coloured illustrations of the commoner species. The keys are very difficult for those without special training.

PLANT GALLS

(24) *British Plant Galls.* E. W. Swanton (Methuen). An old book, now long out of print, but with some good illustrations.

Animals

MAMMALS, AMPHIBIANS, AND REPTILES

(25) *A Beast Book for the Pocket.* E. Sandars. (Oxford.) Contains descriptions and interesting facts about domestic and farm animals, as well as wild animals. Illustrated in line and colour.

(26) *Animal Life of the British Isles.* E. Step. (Warne.) Restricted to wild animals, but is splendidly illustrated in colour and half-tone with excellent photographs.

BIRDS

(27) *Birds of the Wayside and Woodland.* Coward. Edited by Enid Blyton. (Warne.) Coloured illustrations of all our British Birds, and probably the best book of its kind for young naturalists.

INSECTS

(a) Butterflies and Moths.

(28) *Simple Experiments with Insects.* H. Kalmus. (Heinemann.) Describes numerous experiments on insect behaviour and physiology. Though some of the experiments are rather academic, others should appeal strongly to the naturalist.

(29) *Butterflies of the British Isles.* R. South. (Warne.) Coloured illustrations.

(30) *Moths of the British Isles.* (First and Second Series.) R. South (Warne). Coloured illustrations of all the moths, and half-tone illustrations of many caterpillars and pupæ. There are no keys, but the illustrations and descriptions are usually adequate for the identification of species.

(31) *The Caterpillars of the British Butterflies.* W. J. Stokoe (Warne). Contains a section on rearing, and treats also the eggs, pupæ, and food plants. Illustrated.

(b) Dragonflies.

(32) *The Dragonflies of the British Isles.* C. Longfield. (Warne.) Contains coloured and other illustrations of all the British species. There are keys, but they require some experience to be used correctly.

(33) *Collecting Dragonflies.* A. F. O'Farrell. (Amateur Entomological Society Leaflet No. 12.) This is a most useful pamphlet on collecting and rearing dragonflies. It is well illustrated. Price 7d., post free, from C. B. Pratt, 1, West Ham Lane, London, E.15.

(c) Ants, bees, and wasps.

(34) *Bees, Wasps, Ants and allied orders of the British Isles.* E. Step. (Warne.) Useful for identification of the bumble bees, cuckoo bees, and ordinary wasps. A good section on gall wasps. The other hymenoptera can be identified only roughly. No keys, but very many illustrations, mostly in colour.

(35) *Wasps.* British Museum (Natural History) Miscellaneous Publication No. 44. Price 4d. An excellent pamphlet devoted to the genus *Vespa.* It contains descriptions of the wasps, details of the life histories and foods, and describes methods of control. One coloured plate and one half-tone illustration.

(36) *The Humble Bee.* F. W. L. Sladen. (Macmillan.) An old book now, this is still a useful source of information about bumble bees and cuckoo bees. The coloured plates are extremely good. Instructions are given for capturing bumble bees' nests and keeping them in captivity.

(37) *British Hymenoptera.* Buckhurst, Staniland and Watson. (Arnold.) An introduction to the structure and habits of various British Hymenoptera. It is not written in "popular" style but is as simple as possible without sacrificing accuracy. Keys are provided which should enable a student to identify approximately most captures. There are some excellent photographs of set specimens, and also of insects that mimic Hymenoptera.

(d) Beetles.

(38) *Field Book of Beetles.* J. R. Dibb (A. Brown & Sons). A book which enables one to name the more common beetles, chiefly by means of comparing specimens with illustrations. The situation in which a specimen was found must be known. Hence the book is of value particularly to the field naturalist.

(39) *British Beetles, their Homes and Habitats.* N. Joy. (Warne.) Written by an acknowledged authority, this book will serve as a very useful introduction to the group. Many species are illustrated.

(e) Mosquitoes.

(40) *British Mosquitoes and their Control.* British Museum (Natural History) Economic Series No. 4A. Price 4d. Has a key and descriptions of the British Species.

SPIDERS

(41) *The Spiders and Allied Orders of the British Isles.* T. Savory. (Warne.)

(42) *British Spiders, their Haunts and Habits.* T. Savory. (Oxford.) Illustrated.

MOLLUSCS

(43) *Shell Life.* E. Step. (Warne.)

EARTHWORMS

(44) *British Earthworms and how to Identify Them.* H. Friend (Epworth Press.) A very small book containing descriptions of the British species, but although intended for beginners, it is not particularly easy to use. Illustrated.

WOODLICE

(45) *British Woodlice.* Sillem and Webb. (Duckworth.) Contains excellent descriptions and illustrations of the British species known in 1906 when it was written. It is now difficult to obtain.

REFERENCE BOOKS FOR THOSE WITH BIOLOGICAL TRAINING

(46) *British Plant Life.* W. B. Turrill. (Collins.)

(47) *British Flora.* Bentham and Hooker. (Reeve.) Two volumes of illustrations published separately.

(48) *The Students Handbook of the British Mosses.* H. N. Dixon and H. G. Jameson. (Wheldon and Wesley.)

(49) *A Practical Handbook of British Beetles.* N. Joy. (Witherby.) Two Volumes. Volume I consists of keys, and Vol. II of illustrations.

(50) *British Ants.* H. Donisthorpe. (Routledge.) Keys and descriptions of species.

(51) *Textbook of Entomology.* A. D. Imms. (Methuen.)

(52) *British Butterflies.* E. B. Ford. (Collins.)

(53) *The British Mosquitoes.* J. F. Marshall. (Brit. Mus. of Nat. History.)

(54) *British Snails.* A. E. Ellis. (Oxford.)

(55) *Adaptive Coloration in Animals.* H. B. Cott. (Methuen.) A comprehensive treatment, lavishly illustrated with line drawings and photographs of a high quality.

(56) *A Key to the British Water Bugs (excluding Corixidæ).* T. T. Macan. (Scientific Publication No. 4. Freshwater Biological Assoc. 1s. 6d.) *N.B.*—Also published by the same Association is *A Key to the British Species of Corixidæ*, by T. T. Macan. 1s. 6d.

(57) *Wild Flowers in Relation to Insects.* Sir John Lubbock. (Macmillan.) Long out of print (fourth edition in 1882). Contains much information concerning pollination mechanisms.

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